Technical Bulletin No. 1167

THE HIGH PLAINS

Grasshopper

A Compilation of Facts About Its Occurrence and Control

U. S. DEPARTMENT OF AGRICULTURE

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A Compilation of Facts About Its Occurrence and Control

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UNITED STATES DEPARTMENT OF AGRICULTURE

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PREFACE

Assembled in this publication are all the important facts we know about the High Plains grasshopper *(Dissosteira longipennis* (Thomas)), and records of its occurrence and of Federal, State, and farmer-rancher efforts to control it. These facts are presented for the use of control and research workers.

This information heretofore has been unavailable except to those who searched diligently and at length. Published records of the species are voluminous but scattered and sketchy. Many of the useful facts, particularly on control operations, have been recorded in unpublished official records or in newspaper stories published locally during outbreaks.

This publication is intended to serve six major purposes:

First, it traces the transformation in economic status of an insect species. The High Plains grasshopper, long considered as being nonmigratory and injurious only to small areas of range grass, became strongly migratory and seriously damaged range grasses and crops over an extensive region.

Second, it demonstrates the latent danger of the High Plains grasshopper. Since *longipennis* is economically important only at intervals, the public and some entomologists forget it or discount it between outbreaks.

Under the influence of a combination of favoring circumstances, the High Plains grasshopper could again increase with astounding rapidity into major outbreak proportions—if signs of its resurgence are unnoticed or ignored. The possible cost of such negligence may be estimated from results of the most recent outbreak—that of 1933–40. That outbreak had a calamitous effect on the agricultural economy of five States, demoralized the business life of towns in the infested areas, and interfered with the conduct of regular governmental functions of the States and counties involved.

Third, it describes the nature of this insect enemy—its biology, distribution, range, and habitat—and defines geographical, topographical, and climatic factors that limit or favor increase and dissemination.

Fourth, it shows the influence of natural enemies of *longipennis.*

Fifth, it includes information that will help in the control of the grasshopper both during and between outbreaks.

Since the habitat of *longipennis* is a comparatively small area, it is practicable to find population concentrations when they begin to form and to eliminate the grasshoppers at nominal cost. Injurious infestations cannot develop if population nuclei are destroyed.

Should large-scale control operations again become necessary, facts to form a reliable basis for planning and conducting such operations can be gleaned from records of experience of ranchers and State and Federal agencies in control of the species during the years 1937 to 1940.

Sixth, this compilation reveals the many gaps in our scientific knowledge of this grasshopper and discloses realms in which further research is needed.

Acknowledgments: Many persons furnished or verified information used in this publication. Their assistance is gratefully acknowledged. Among these are entomologists, State officials, newspaper editors, and curators of insect collections.

CONTENTS

THE HIGH PLAINS Grasshopper

INTRODUCTION

The High Plains grasshopper[1] inhabits only the High Plains of the United States. Within that geographical region it has reached outbreak proportions in parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas.

The High Plains grasshopper was considered to be of minor importance for a quarter of a century after it was discovered in 1867. During the next 42 years, a few small, short-lived outbreaks aroused apprehension that the species might become migratory and destructive. This apprehension was justified by the behavior of *longipennis* during the widespread outbreak of 1933–40.

In the outbreak of 1933–40 adults of this species flew hundreds of miles, and bands of nymphs made countywide marches. It became necessary to conduct costly, extensive control operations to save large areas of range forage from complete destruction. Baiting, the main control method, began in 1937 and increased in intensity and design during each of the succeeding two years. By 1940, baiting and control by natural agencies—birds, weather, animal and insect predators, and insect parasites—had checked the outbreak. The cost of control operations during this outbreak was approximately 2¼ million dollars.

There have been no *longipennis* outbreaks since 1940. From 1940 until 1951, when abnormally wet weather in the High Plains was probably the main deterrent to population increase, survey revealed the presence rarely of only single specimens. Although the weather since 1950 has favored population increase, it was not detected until 1955 when a light infestation was found in a small area in southern Union County, New Mexico. Some eggs were laid in the fall on land owned by a rancher who remembered the devastation wrought by the last outbreak. He plowed under known small egg beds, so controlled the main infestation. Range land in the southern part of Union County was sprayed in 1956 to control range species one of which was the High Plains grasshopper. After the control season, however, live adults were found widely scattered outside of the controlled area so the infested area was larger in 1956 than it was in 1955. Doubtless the expected increase did not materialize during the four drought years (1951-54) because the species was so nearly extinct that a population buildup began very slowly.

[1] *Dissosteira longipennis* (Thomas).

The High Plains grasshopper was not found in 1957 in the area in Union County that was sprayed in 1956, but a spring survey in 1957 disclosed a light infestation further south in the same county. This was sprayed after the High Plains grasshoppers had become adult, again to control a mixed population of range species. Later, living High Plains grasshoppers could not be found in the sprayed area but neither could many dead ones. However, dead grasshoppers of that species were found on distant unsprayed land, so it was assumed that adults had taken wing after they were sprayed and had died elsewhere. After control operations were completed about midsummer 1957, another small infestation of the High Plains grasshopper was found in Union County, N. Mex., south of that area that was sprayed that year.

Another major outbreak need not occur. When concentrations of grasshoppers mark the beginning of *longipennis* outbreaks, control can be accomplished at a fraction of the cost that would be required if the opportune time were neglected. The key to prevention of outbreaks is watchfulness in the form of well-organized surveys made annually and prompt control action to stamp out small concentrations of grasshoppers when they are found.

ECONOMIC EFFECT

The High Plains grasshopper was for many years considered to be only a range-grass feeder. Even when it reached outbreak proportions in Lincoln County, Colo., in 1891, it was not looked upon by competent entomologists as a potential enemy of planted crops. When Bruner *(13)*[2] investigated the Colorado outbreak he said *(p. 19)*:

> This insect . . . covered an area of about 400 square miles of territory in sufficient numbers to materially injure the grasses growing on the ranges of the entire region, and amongst these grasses the species of *Bouteloua* or Gramma grasses, and the Buffalo Grass, *Buchloë dactyloides*. Grains and other cultivated plants did not appear to be especially attractive to it. In fact very little or no injury was done by it to the cultivated crops growing within the region infested. . . .

Popenoe visited the same infestation that year, and an abstract of his report to the Association of Economic Entomologists stated *(68, p. 41)* that grasshoppers "traveled over bluffs and rounded hills, eating the buffalo and gramma grass," and that "They are credited with all the destruction which has been done by all kinds of insects, and he [Popenoe] thinks that they did but very little

[2] Italic numbers in parentheses refer to Bibliography, pp. 156 to 168. If the number is followed by an asterisk, the reference is to the list of typewritten reports, insect collections, correspondence, and manuscripts, p.163; a number without an asterisk refers to the list of publications, p. 156.

damage to potatoes and corn, although marching through the fields in great numbers. At the time of his visit they were marching through wheat fields in the same way, but since he left they have done some damage to this crop."

Bruner *(19, p. 38)* continued to study the species, and after 5 more years had elapsed expressed alarm that it might be accommodating itself to feed upon a wider variety of plants. He said:

> The only remaining species of locust that was found by me to be harmful this year is *Dissosteira longipennis;* and from the fact that it actually attacked a number of cultivated plants not heretofore reported as being in its bill of fare, we may be pardoned if we are somewhat apprehensive concerning it as to the future. It actually destroyed entire fields of small grain, some corn, potatoes, and a number of garden plants in the vicinity of Lodge Pole and Sidney . . . Although it still seems to prefer the grama and other short grasses of the plains, the fact that it has destroyed the above-named cultivated plants would indicate that it is capable of harm when opportunities for so doing are offered.

Smith *(87, p. 6)* in 1913 found that in New Mexico, although the High Plains grasshopper preferred the short grasses, it readily fed upon many cultivated crops:

> Fields of maize, kafir corn, and millet were completely devastated. Millet is in all instances a most desirable food plant. Mr. Hobson, of Elida, informed the writer that he noted the grasshoppers massing in 5 acres of millet on his farm, and in less than 30 minutes every plant had been eaten to the ground. Sorghum is fed upon to a slight extent, but is seldom disturbed if other more desirable food plants are readily available.
>
> Truck crops in the infested area were entirely defoliated . . .

In the first record of the species where control was undertaken in 1921, Corkins *(28, p. 37)* spoke of the damage to cultivated crops:

> While on the march, nymphs, passing through native vegetation, would clean up Grama and Buffalo-grass as they went, leaving only weeds. Corn, beans, cane and sudan-grass were the principal cultivated crops in this region, and all were attacked. Sometimes when a field of corn was encountered, for some unknown reason, the army of nymphs would split and go around it. At other times they would go directly through, partially or totally destroying the plants.

Little information is available concerning the effect of the High Plains grasshopper on cultivated crops in the early part of the buildup of the 1933–40 outbreak. McCampbell *(35*)* reported:

> My own observations during 1934 and 1935 are that nymphs may feed on almost any cultivated crops they encounter. Migrating adults strongly prefer native grasses but have been found very destructive to fall wheat and feeding to a limited extent on the heads of maize. A few cases of sudan being destroyed are reported in Baca and Las Animas Counties in southern Colorado in 1936.

McCampbell *(38*)* recorded loss or damage from the High Plains grasshopper in Colorado in 1937 as follows:

> More than 2,500 acres of crops have been severely injured. (Otero County) . . . Most of the grasshoppers that were not killed in this county have left. . . . More than 30,000 acres of crops have been severely damaged. (Baca County) Losses include about 10,000 acres

of crops completely destroyed and 3,000 acres damaged. (Las Animas County) Migratory hoppers are doing much damage to crops near Walsenburg, Rattle Snake Buttes, Turkey Ridge, and Turner. . . . Crops have been seriously damaged in a fourth of the county. (Huerfano County) . . . A band of *D. longipennis* flew onto the ranch of L. H. Fields in Lincoln County and in three days entirely consumed the grass on 25,000 acres of land, forcing the owner to sell his entire herd of 500 cattle.

F. A. Morton *(48*)*, after investigating the infestation in Lincoln County, Colo., in June 1937, reported:

Practically all of the grass within the infested area had now been . . . stripped by marching bands with the exception of those ranches that are being protected by baiting operations. Crops of all kinds were less than 4 inches high and were cleaned to the ground wherever bands crossed. Known forced sales of livestock were as follows:

Frank Smith, sold 700 cattle—entire herd.
Les Jurgen, moved 1,000 cattle—entire herd.
R. W. McAllister, sold 250 cattle—entire herd.
Tom McCullen, sold 200 cattle—entire herd.
Al. Barndale, sold 250 cattle—entire herd.
Patterson and Scott, sold 200 cattle—entire herd.
B. F. Ross, sold 250 cattle—entire herd.
Mr. Lochdahl, sold 150 cattle—entire herd.
Weston Properties, sold 1,000 cattle—moved 1,000.
George Shaffer, sold 600 cattle—one-half of herd.
Alec Matheson, sold 3,000 sheep.
Brett Gray, sold or moved 12,000 sheep.

L. S. Kurtz *(19*)*, Extension Agent, Union County, N. Mex., reported:

The first crop damage noted was to sudan grass the tenth of June [1938]. It was necessary for a number of farmers to replant their crops two and three times, especially where sudan grass and millet were planted. For the most part, the 'hoppers confined their feeding to range land which was composed mostly of blue grama grass; however, where they did strike a field of good sudan, millet, or beans, they generally made a clean sweep.

Ben Ehrlich *(40*)*, County Agricultural Agent, Phillips County, Colo., reported in 1938:

Hordes of migratory grasshoppers are flying in from the south nearly every morning. Edges of cornfields have been severely damaged. Several stands of millet, cane and sudan grass have been destroyed. Many farmers have cut small grain while it was green to save as much of it as possible.

McCampbell *(40*)* reported other losses in Colorado in 1938. Lincoln County: 25,000 acres of good grass destroyed; more than 1,000 head of cattle forced to be sold when deprived of grazing grass; 200 sections of grasslands and 3,000 acres of crops severely damaged. Baca County: More than 30,000 acres of crops severely damaged. Las Animas County: Close to 10,000 acres of young crops destroyed. Kiowa County: 300 sections of grasslands and 500 acres of crops damaged. Cheyenne County: In 2 days, grasshoppers devoured the grass covering on 4 sections of land.

There are few records of specific losses of cultivated crops in published literature or in the reports of State leaders and control supervisors who were concerned with the 1933–40 outbreak. Yet men who worked on control during that period recall that prac-

tically all crops were seriously injured or destroyed when dense bands of this grasshopper migrated into them. It has been evident from the data studied that, although alfalfa has been invaded many times by *longipennis,* it has rarely been fed upon and then not seriously damaged. Reports of the grasshoppers feeding on many grasses or weeds are so numerous that there appears to be no object in listing the species of plants attacked. There is no doubt that *longipennis* causes damage primarily to the short grasses, principally to the grama grasses and buffalo grass (figs. 1, 2, and 3). When the grasshoppers leave preferred food-plant areas, either in search of food or because of population pressures, they damage or destroy most species of range grasses or cultivated crops through which they migrate.

Isely *(49, pp. 65-66)* said: "Morphologically, mandibles are definitely correlated with food . . ." "Food specificity appears to offer tangible clews toward a better understanding of grasshopper communities and the interrelationships between . . . Orthoptera and plants." "It should be evident that food specificity research will contribute to further progress in working out the control of pest hoppers." The species of the Oedipodinae which he studied for mandibular structure and which he tested for food preference, he grouped on similarity of mandible models. These he found to

BN-1944

FIGURE 1.—Blue grama-buffalo grass range in Yuma County, Colo., 1939, protected from grazing.

BN-1943

FIGURE 2.—Range in eastern Colorado before being fed upon by *longipennis*, 1939. (Photo by Colorado State University.)

BN-1942

FIGURE 3.—Appearance of range in eastern Colorado soon after it was invaded by *longipennis*, 1939. (Photo by Colorado State University.)

parallel feeding behavior. He concluded that mandibles of the Oedipodinae are of three patterns: grass-feeder, forbs-feeder, and mixed-feeder, and that *longipennis* is a grass feeder while *carolina* is a mixed feeder. Although *longipennis* definitely is primarily a grass feeder, judged by the number of times it is known to have fed on other than grass plants, it must be considered also as a mixed feeder on occasion.

Estimates of crop and range losses caused by the High Plains grasshopper are nonexistent prior to 1921, although Smith *(87, p. 3)* said of the 1913 outbreak in New Mexico, "this species extended over 400 to 500 square miles, the prairie grasses, grain, and garden crops within this area being in great part devastated." Corkins *(28)* estimated the potential acreage of crops saved by the control program in 1921 at 80,640 acres.

Henry Bledso, interviewed at his ranch in 1952, told how adult grasshoppers flew onto his rangeland in El Paso County, Colo., in the fall of 1937, destroyed all forage on about 5 of the 20 sections he held, and severely reduced the forage on an additional 5 sections. He had to find other range and buy 100 tons of hay to replace the forage destroyed on his winter range. He moved his cattle to range in Crowley and Otero Counties in 1938 only to have the forage for winter feed again destroyed; he was forced to spend $7,500 for hay to carry his stock through the winter. This loss was exclusive of his cost for locating grasshopper bands and hauling and distributing bait to protect some of his winter range.

Spain *(71*)* said that in Briscoe County, Tex., in 1939:

> . . . part of a band of *longipennis* had migrated from a pasture into green wheat just heading out. An estimated 99 percent control had been attained in both wheat and pasture although it took three applications of bait in the wheat to get the same percent kill in the pasture with one spreading. 10 percent of the leaves and 2 percent of the wheat heads were stripped and cut off.

In Baca County, Colo., 1939, Scharff *(56*)* reported:

> On the Brooks Brinkley ranch . . . is an egg bed of 20 acres, situated on level disced cropland, part of which is planted to wheat, now 6 inches high. Two acres of the egg bed extend into the wheat. . . . The hatch was estimated as 50 percent complete . . . and in the wheat, 50 per square yard, all first instar. . . . There was considerable evidence of feeding having been done on the wheat.

In Colorado in 1939, Davis and Mickle *(3*)* concluded:

> Practically all destruction by *longipennis* 'hoppers was to the grasses of the native prairie. However, in some cases, they migrated into grain crops and accounted for considerable damage to those crops.

T. R. Hupper *(41*)* in 1939 said:

> Crop injury was first noticed on early plantings of spring wheat, winter wheat, and barley. Due to the lack of attractive plants on the margins of fence rows the 'hoppers quickly marched into the fields . . . in search of food. . . . In one case *D. longipennis* hatched within a field planted to wheat and as the tender shoots appeared the first-, second- and third-instar nymphs cut them down. . . . Incidentally, *D. longipennis* did not seem to develop at the normal rate on a diet of wheat; buffalo grass wa ssuperior in this respect.

Many specific reports or estimates of damage caused by *D. longipennis* appeared in items in newspapers in the infested areas during outbreaks. Four such items are briefed below.

The Mountain and Plain Weekly, Denver, Colo., on July 20, 1937, reported that eastern Colorado stockmen were moving cattle to market because the grasshoppers had left nothing for the cattle to eat. The grasshoppers were forcing the sale of breeding stock as well as of market beef. In Lincoln County, it was reported, 1,000 head of cattle had already been sold. In Kit Carson County 10,000 acres of green barley and 5,000 acres of other crops had been eaten by the grasshoppers.

According to a news item in the Amarillo (Tex.) News, May 21, 1938, the grasshopper situation was more serious than drought in the Panhandle of Texas, particularly in the northwest tier of counties. The grasshoppers at that time were beginning to march in ranch sections of Dallam and Hartley Counties. A local rancher predicted that it would take State and Federal action plus all the local cooperation possible to combat the plague.

Table 1.—Crop and range grass losses from Dissosteira longipennis *and crops and range saved by control, as estimated from data compiled from all authentic sources* [1]

State and year	Crops		Range	
	Loss [2]	Saved by control [3]	Loss	Saved by control
Colorado:				
1936	----------	----------	10,000 acres destroyed.	
1937	22,818 acres damaged.	$37,431	$211,440	$60,000
1938	$22,647	$451,546	$304,426	$964,500
1939	Slight	----------	Slight	----------
New Mexico:				
1938	$602	$118,681	$13,600	$804,904
1940	None	----------	None	----------

[1] Although *longipennis* was present in Colorado, Kansas, New Mexico, Oklahoma, and Texas for several years, no data are available on losses or savings for years and States other than those shown in this table.

[2] Where a figure is given for loss it was derived as follows: Losses were totaled in all counties in the infested areas for all crops except alfalfa, sugar beets, truck crops, and native hay; 10 percent of this total was estimated to be the loss caused by *longipennis*. This is considered a reasonable and conservative estimate, since all such crops were attacked by the species and often destroyed by them.

[3] Each figure for crops saved by control was derived as follows: All crops harvested in the infested area (except alfalfa, sugar beets, truck crops, and native hay) were totaled; 10 percent of this total was estimated to be the amount saved by control.

Source: Based on data from McCampbell *(35*, 40*)*, Mickle *(42*)*, and Hildwein *(19*, 21*)*.

An editorial in the Moore County (Tex.) News, June 2, 1938, described the "march of death accompanying this section's worst grasshopper invasion." The writer traveled for miles and found no letup in the infestation. Squirming hordes of grasshoppers were stripping the foliage and heads from wheat stalks, then marching on to threaten everything green in their way.

In June 1939 the Amarillo Daily News reported that damage estimated to be between $500,000 and $1 million had already been done by grasshoppers in Dallam, Hartley, Sherman, and Moore Counties.

Reports are replete with statements that *longipennis* destroyed or severely damaged range grasses wherever bands of grasshoppers marched over the range or invaded it by flight. From 1936 to 1940, 10,927,313 acres were baited to control the species. An extremely conservative estimate therefore is that, without control, about 10,000,000 acres of grass would have been destroyed. Since most of the baiting was to kill concentrations of grasshoppers near their eggbeds or hatching grounds, it is reasonable to conclude that if their spread had not been deterred by baiting they would have destroyed grass greatly in excess of the acreage baited.

When drought and severe grasshopper damage occur simultaneously it rarely is possible to distinguish which causes the greater loss. A combination of the two usually results in complete range or crop loss unless it is prevented by an effective grasshopper-control program. Losses, and savings resulting from control, are listed in table 1.

POLITICAL EFFECT

Injurious outbreaks and the human pattern of action to combat them are similar for many species of grasshoppers. Light infestations generally are ignored as long as they do not cause easily detected damage to farm or range crops. When a major outbreak occurs, vegetation is attacked over such a widespread area that control by individuals is hopelessly impracticable or prohibitively costly. The economic effect of an outbreak then influences political action intended to avert disaster. Individuals or communities request or demand assistance in some form from governmental agencies, local or national. Sooner or later most of those requests concerned with major outbreaks are channeled to reach the United States Department of Agriculture, either directly or through the people's elected representatives to Congress.

In most outbreaks, grasshopper devastation, arousal of public interest, and eventual control operations occur in about the same sequence. This sequence and the political impact of an outbreak of the High Plains grasshopper are illustrated by a few case happenings.

In the fall of 1912 ranchers in Roosevelt County, N. Mex., had warning of an impending outbreak when they saw hordes of flying grasshoppers alighting on the range, but since they had had no experience with similar invasions they did not recognize the

warning. Consequently, the 1913 outbreak was not expected and no plans were made for controlling it. The situation is graphically described by Harrison E. Smith *(87, p. 4)*:

> This outbreak originated from a tremendous swarm of adults flying from some unknown point to the north. These settled in the outlying districts of Elida, N. Mex., during the latter part of August and early September. During one evening, when swarms of this species were passing over Elida, large numbers of them flew against the plate-glass window of a brilliantly lighted barber shop. The following morning several bushels of dead grasshoppers were heaped on the sidewalk.
>
> The breeding grounds on which these swarms settled to deposit their eggs were in most part in a chain of sandhills running from about 8 to 10 miles northwest to southwest of Elida. . . .
>
> On May 4, 1913 . . . Mr. B. W. Kinsolving noted the tiny grasshoppers coming out of the sand "by the million." Watching this area for a little over a week Mr. Kinsolving says: "Tiny hoppers appeared to be coming out of the sand continually. One evening during a heavy shower certain areas of this breeding ground were covered at least 6 inches deep with tiny hoppers."
>
> On May 6 . . . Mr. Bruce Marsh noted the tiny grasshoppers issuing from the sand in an area nearly 1 mile square, "the ground over this area appearing like a living mass of crawling maggots."
>
> At about the same time the cowboys on the Littlefield ranch . . . noted the sand moving up and down over a great area. When examined they found "countless millions of tiny hoppers crawling to the surface."

Faced abruptly with complete range devastation by a full-fledged outbreak, ranchers in the infested area sought help through public agencies. They took their problem to the local postmaster, probably because he was the Government official most readily available. In the United States Archives in Washington, D. C., is a chronological record that shows how the service of the Department of Agriculture was enlisted in the 1913 outbreak. The following telegram, dated May 24, 1913, was addressed to the Secretary of Agriculture:

> The grasshopper plague has come to our country and they are here by the billion. Just south and west of town and we want you to send someone here at once in an endeavor to eradicate them before they destroy the whole agricultural crops. act as soon as possible for the grasshoppers are multiplying rapidly and moving northward.
>
> Henry Rankin, Postmaster,
> Elida, N. Mex.

The Secretary of Agriculture responded by telegraph to Mr. Rankin's appeal:

> May 24 telegram received. Representative Bureau of Entomology instructed to proceed from Roswell to Elida at once to investigate grasshopper situation.
>
> Houston.

The representative referred to undoubtedly was A. G. Hammar who was stationed in Roswell, N. Mex., for on May 25 A. L. Quaintance, of the Bureau of Entomology, received from this field assistant a telegram reading:

> Hoppers at Elida of migratory habit. Originated from swarm that settled this part of country last fall. Are all grazing. Country very sparsely settled of which over 100 square miles are infested. Have

advised moving of stock from infested section. Hoppers migrating now due northeast and have progressed 10 miles in three weeks.

A. G. Hammar
Elida, N. Mex.

Although the addressee is not named, the following telegram of May 26 probably was sent to a Member of the New Mexico Congressional delegation:

Will you please get some immediate action from the Department of Agriculture on matter of assistance to local man in endeavor to control immense swarm migratory grasshoppers extending between Elida and Kenna, moving northeast Portales Valley and Santa Fe railroad now active with men and money. Have Department of Agriculture refer to wire and report their local man Hammar. These hoppers constitute considerable menace to eastern States.

A. A. Rogers
Roswell, N. Mex.

E. O. G. Kelly was then in charge of a Bureau of Entomology field station at Wellington, Kans.

In the chronological sequence of events we deduce that the problem of the New Mexico grasshopper outbreak was then referred to F. M. Webster, chief of the Division of Cereal and Forage Insect Investigations, for the Archives record contains the following telegram:

Washington, D. C.
May 29, 1913

E. O. G. Kelly
Wellington, Kans.
Smith detailed New Mexico, see Postmaster Rankin at Elida. . . .

Webster.

Mr. Kelly wrote Webster June 2:

Your telegram of today has just been received. Smith has started to New Mexico, will be in Amarillo today for consultation with the A. T. and S. F. freight agent and will go right on to Elida tomorrow. . . .

Yours very truly,
E. O. G. Kelly.

Mr. Webster wrote Kelly, June 2:

I certainly hope that Mr. Smith will make good in managing the grasshopper outbreak. . . . I have a telegram from him saying that he is leaving Amarillo today in company with the Santa Fe Railroad expert.

Publicity on the outbreak apparently made the local papers first on May 30, 1913, when the Clovis Journal reported that an invading army of grasshoppers had been seen "down the line south." The "advancing column" was reported to be 5 miles deep and nearly 20 miles wide; it was moving northeastwardly, directly toward Clovis.

Shortly after this first report, the outbreak made headlines through a release by the Department of Agriculture. In the USDA release, F. M. Webster of the Bureau of Entomology said that "this looks like a grasshopper year." The release said further that the U. S. Department of Agriculture regarded the New Mexico outbreak so seriously that an expert in the Division of Cereal and Forage Insect Investigations had been ordered to the scene of the trouble.

Colorado, 1936 to 1938

When the High Plains grasshopper invaded eastern Colorado in the fall of 1936 Sam C. McCampbell *(35*)*, State leader of grasshopper control, after making an investigation, estimated that adults laid their eggs over an area involving 2 million acres of rangeland. From the extent of the migration he sensed the need for control in 1937 when he said: "Because of the sparsely settled nature of the country infested with *longipennis* and the low productivity of the land, outside aid will be necessary both in the form of poison bait and supervisional help. The success of our 1934 campaign was largely due to Federal aid in the form of bran and sodium arsenite and an entomologist in the field. Residents of this section are hoping for such help in 1937."

The Colorado Legislature in 1937 sent a memorial to the President of the United States, to the Secretary of Agriculture, and to Members of Congress urging passage of a bill providing $5 million for the control of grasshoppers, Mormon crickets, and other insects similarly subject to interstate migratory movements. The amount appropriated under the bill was $2 million. McCampbell *(38*)* said: "The appropriation was all spent early in July and only through timely passage of a second appropriation for $1 million was Colorado able to meet the serious 'hopper invasion. It is estimated that $9 million in crops was saved through this year's hopper campaign. The $3 million loss from grasshoppers would certainly have been much lower if adequate funds had been provided earlier in the season."

The Governor of Colorado was besieged by requests for aid in 1937 after manpower and money for continuing the control fight were nearly exhausted. He investigated the situation personally, as reported in the July 2 issue of the Eastern Colorado Plainsman and Range Ledger.

The newspaper report, briefed below, reveals the seriousness of the economic effects of the outbreak and its political significance.

According to the report, the Governor visited the fields near Hugo where grasshoppers were feeding and observed the damage. He talked to the county agent and was informed that poisoning crews, which had been working for a week spreading poison in the vicinity, could not fight the grasshoppers by themselves. "It's a superhuman task for a vast army of workers," said the agent. The Governor then called out the National Guard to help in the fight and appealed to the WPA for a blanket project.

On July 13, 1937, the Denver Post published a news item concerning State assistance: "One hundred and thirty-six [National Guard] trucks were sent into southeastern Colorado about 2 weeks ago and have been fighting the plague there from headquarters in Colorado Springs."

Aroused by the economic and political effects of the 1937 outbreak, Governor Teller Ammons, on February 23, 1938, outlined his view of the problem that year in a memorandum to F. A. Anderson, director of the Colorado Extension Service. Excerpts from the memorandum *(40*)* emphasize how a grasshopper outbreak influences political action:

The destruction of crops by insect pests is one of the greatest hazards constantly confronting farmers of eastern Colorado and is of more serious consequence even than the failure to produce crops because of serious drought, as has been our experience in varying degrees for seven consecutive years. Losses incurred from destruction by insect pests include not only the investment in land and equipment, but the expense of planting and cultivation.

Senators Alva B. Adams and Edwin C. Johnson, and Congressmen Edward Taylor, John A. Martin, Lawrence Lewis and Fred Cummings, comprising Colorado's delegation to Congress, this year as last, initiated an early effort with the cooperation of their colleagues in obtaining Federal aid. After conferring with the Director of the Budget, arrangements were made for the introduction of a joint resolution for approximately $2,000,000 for the control of grasshoppers and other insect pests. This resolution was approved by the House of Representatives on February 17, and received favorable consideration by the Senate Appropriations Committee with the prospect of its early passage by the Senate, as reported in a telegram received on February 18 from Senator Adams.

Several weeks undoubtedly would have elapsed in making Federal funds available had the appropriation been permitted to remain with the hundreds of other items in the regular agricultural appropriation bill now in Congress. We are, therefore, indebted to our Senators and Congressmen for their aggressive and successful effort to make Federal funds available immediately and in ample time to use them effectively this spring.

When Federal funds were exhausted before the control campaign was completed, the Rocky Mountain News, July 1, 1938, announced action that was taken by the State in the emergency:

Issuance of $25,000 worth of State certificates of indebtedness was ordered yesterday by Governor Ammons to supply funds for a new campaign against grasshoppers. The Governor issued an executive order declaring a state of emergency exists after it was found Federal funds . . . are exhausted and the various counties are without funds. The Governor declared, "I don't believe we can let up now as crop prospects are the best in several years." Attorney General Byron G. Rogers approved the executive order and the issue of certificates which will be presented to the legislature in January for covering the appropriation.

New Mexico, 1937 and 1938

Under the caption "Tingley Joins Hopper War," the Clayton News wrote on June 1, 1937:

Governor Clyde Tingley came to Clayton this noon, had lunch with county officials and after he visited the grasshopper-infested portion of the county, threw resources of the State into the fight.

He ordered out the National Guard trucks and a number of smaller cars. Saturday morning, after an all night drive, these started hauling poison mash to the area. Tingley instructed L. B. Tyson, district engineer, to throw the entire resources of his district into the fight. Now fifteen trucks are running night and day from the mills west of Springer to the area at Clayton, Greenville, and Des Moines.

The Governor instructed the county engineer to order poison, molasses, bran, and necessary supplies to the amount of $15,000. . . .

The Colorado Springs Gazette published a news item datelined Clayton, N. Mex., July 11, 1937:

> A thousand ranchers, farmers, businessmen, soldiers and CCC enrollees formed the determined army that swung into action two hours before dawn.

Captioned "Valuable Assistance by Guardsmen," the Clayton News, July 14, 1937, editorialized:

> If the invasion is stopped, and it looks as if it may be, much of the credit should go to the guardsmen. We here in Union County have appreciated their aid; we could not have gotten along without them.
>
> The State Highway Department is also due our thanks for the splendid way in which they cooperated with trucks and men. . . .

In 1938 the State of New Mexico again threw all available resources into the fight against this grasshopper, as evidenced in a news release June 7 in the Albuquerque Tribune:

> Gov. Clyde Tingley, acting quickly to aid embattled northeastern New Mexico residents fighting an invasion of grasshoppers, called out 30 National Guardsmen to duty in that sector today.
>
> He also ordered 15 National Guard trucks to the area with the troops headed by Adj. Gen. R. C. Charlton.
>
> The Governor announced that orders had been placed for immediate construction of 25 more spreaders. This will bring the number . . . to 80.
>
> "Everything possible must be done this week to lick the grasshoppers or they'll lick us," the Governor declared. . . .

The executive also dispatched a telegram to Gov. James V. Allred of Texas, asking that the Lone Star State cooperate in Dallam and Hartley Counties, bordering northeast New Mexico. "Farmers and ranchers of the northeastern counties have been putting on a real fight," said he.

In an interview in February 1953 ex-Governor Tingley said that, when northeastern New Mexico urged him to help in control of the 1938 outbreak, he drove to Clayton and went out to see the infestations before he decided upon what the State could best do to further control work. He declared that nobody could believe the immensity and density of the grasshopper swarms without having actually seen them. "Where the swarms had passed on," he said, "the ground was as bare as that pavement out there." He saw the necessity for immediately increased control work if crops were to be saved. That evening, he promised 400 ranchers and businessmen assembled in Clayton that the State would give them prompt help. Concerning that promise, J. E. Staley, editor of the Clayton News, said that following the meeting the Governor telephoned his State officials and that by daylight the next morning "State Highway and National Guard trucks were rolling into Clayton with their bed rolls."

Said Mr. Tingley: "It takes money to fight a grasshopper outbreak as big as that. The only thing that was in my mind was to kill the grasshoppers and save the crops. I didn't know where the money was coming from but had the power to assign State personnel and equipment to the job. I called highway trucks from as far as 400 miles away, and called on the National Guard and other organizations under my command, such as the Welfare Department, to furnish available equipment or other facilities.

State personnel and equipment expenses were paid out of State funds appropriated to the various departments for conducting their regular operations." The Governor ordered 100 traction bait spreaders, which were constructed in the shops of the State Highway Department and of the Santa Fe Railroad, hauled to the outbreak area on State-owned trucks, and paid for out of State funds. A separate account of State expenditures for grasshoppers control was not kept, but Mr. Tingley estimated it was at least $50,000, for it included payment of regular salaries, temporary labor, and such items as the maintenance of camps and the feeding of State Highway and National Guard members.

TEXAS, 1938

Texas did not need to organize for control of this grasshopper until 1938. In that year, the feature front-page article of the Amarillo Daily News, June 10, was devoted to the subject. Excerpts from that article follow:

> The fight on the menacing hordes of migratory grasshoppers in northwest Panhandle will take on all the appearances of the war that it is today when 40 Army trucks manned by soldiers take the field to scatter poison.
>
> The 40 National Guard trucks which mobilized in Amarillo yesterday . . . will pull poison spreaders in Dallam, Hartley, Sherman and Moore Counties.
>
> Heavier trucks, from the State Highway Department . . . will haul sawdust from Springer, N. Mex., to the poison-mixing plants and the mixed poison to the range land and fields in which the spreaders are operating.
>
> The Government is furnishing the poison, the WPA is mixing it.
>
> Enlisted men have been assigned to drive the trucks and one sergeant has been assigned to the agricultural agent in each of the four counties. Working with the county agents, the sergeants will give instructions to the truck drivers. The county agents are working with each other and with Ted Houghton, the poison-program coordinator for the four counties. Mr. Houghton and the county agents know where the poison should be spread. . . .
>
> Colonel Perrine talked with the sergeants and drivers and informed them that they would not be under strict military regulations, saying, "Boys, I don't know whether you have ever fought grasshoppers and I want each of you to make a hand. Cooperate with Mr. Houghton, the county agents and your sergeants and make a hand in every respect. . . . We're here to get the grasshoppers before they have a chance to start flying."
>
> The National Guardsmen will be fed and housed by farmers and ranchers. Some of the men will spend several days at a time as far as 60 to 75 miles away from town.
>
> It was at the request of Governor Tingley that Governor Allred ordered the Texas National Guard and highway department into the war.

Measures taken to quell major outbreaks of grasshoppers often require the diversion of funds from projects for which they were appropriated. The effect of such emergency is not so easily measured as crop losses caused by grasshoppers, but it is important

to the economy of a State or a county. Assignment of resources to work other than that for which funds were appropriated results in delay, curtailment, or abandonment of scheduled work.

If grasshoppers were not controlled, officials have faced the prospect of decreased revenues and profitless farm operations that would lead to numerous tax delinquencies and eventually to the loss of a permanent, stable farm population. In many outbreaks that have occurred, responsible officials have chosen to divert regular funds to the grasshopper emergency, reasoning that grasshopper control was more important to their State or county than some work that was already scheduled.

OUTBREAKS RECORDED

Considered from the standpoint of controlling it, a grasshopper outbreak may range in importance from minor to major. It is a minor outbreak if it occurs only locally and, therefore, does not require extensive operations to bring it under control. It also is a minor outbreak when local populations spread to adjacent areas but large-scale control operations are not required to prevent severe damage. A major outbreak is one that affects a large area with grasshopper populations so great that extensive operations are necessitated to control it.

The High Plains grasshopper is known to have developed to major outbreak proportions only during one period—1936–40. This outbreak had its beginnings in local outbreaks in Colorado and New Mexico in 1933. The area infested expanded each year thereafter until it reached its peak in 1939, then it receded rapidly. At least 23,575,000 acres of land in 5 States were infested by economic populations of the High Plains grasshopper during the 5 years of this major outbreak.

The size of infested area, for each year when it was known, was as follows:

	Acres
1891	256,000
1913	288,000
1921	40,320
1934	448,000
1936	2,000,000
1937	3,400,000
1938	6,496,000
1939	11,485,000
1940	194,000

1891

The first authentic report of *longipennis* in outbreak proportions was in 1891, although some of the earlier severe damage to vegetation in one or more of these States might well have been caused by the species. Corkins *(28, p. 35)* reports one such case when he says, "To Mr. F. A. Perkens, County Assessor of El Paso County, [Colorado], we are indebted for the record that, in 1873, grasshoppers completely cleaned up the vegetation in the county. There are no definite data which prove the identity of the locust concerned, but it is altogether possible that it was this species."

The local outbreak of 1891 was sufficiently unusual and destructive to make press headlines. In a column of news items captioned "Railroad Couplings," the Goodland, Kans., News, June 25, 1891, said: "At Limon [Lincoln County, Colo.] trainmen are having 'plenty trouble' with the grasshoppers. The insects get on the rails and, when run over, grease the iron and drivers so that it is impossible to pull a load up the grade."

On July 16 the Daily News (Denver, Colo.) published an eyewitness account of the grasshopper outbreak sent in by a reporter who had been dispatched to Arriba, in the part of the State where an invasion of grasshoppers had been reported. According to the account a swarm at least 23 miles wide and 70 miles long was on that day centered about Bovina. The grasshoppers would not be able to fly for another 2 weeks but they were hopping eastward 2 to 4 miles a day. The swarm was made up of the young of grasshoppers that had been in the same area the year before; now they had increased many fold.

The report went on to say that the grasshoppers stopped every westbound train that went through Arriba at night. The grasshoppers clustered on the rails, which were warmer than the cold night air, and almost hid the rails from view. When a train attempted to climb the upgrade, its drive wheels would revolve but slide helplessly upon the rails. Much anxiety was expressed by the citizens in Colorado for the welfare of Kansas, which was in the path of the grasshoppers.

When news of the outbreak in Colorado reached the Department of Agriculture in Washington, D. C., C. V. Riley, entomologist for the Department, dispatched trained entomologists to the scene to ascertain the correctness of the reports being received. Lawrence Bruner, entomologist for the University of Nebraska and a leading authority on Orthoptera, was one of the entomologists commissioned for the task. When he had finished his investigation he wrote *(13, pp. 18–19)*:

> During the early part of July reports came from the eastern and southeastern portions of Colorado of locust depredations. The first of these was that trains had been stopped by grasshoppers getting on the rails of the Santa Fe Railroad 100 miles or thereabouts east of Denver. Shortly after this report appeared in the newspapers of serious damage being done around the point where they were first mentioned as stopping trains. . . . On the strength of these reports Professor Riley instructed me to visit the localities for the purpose of ascertaining the extent of country overrun, the actual and possible future injury which might result, and the exact identity of the species concerned. . . . I first visited Akron, Colorado, the nearest point on the Burlington and Missouri line to the region infested. There securing a team and driving to the south only about 6 miles the advance guard of the enemy was encountered. Imagine my surprise at finding here an entirely new insect as far as destructive locusts are concerned. Here in Colorado, and in immense numbers was the *Dissosteira longipennis*, an insect usually considered rare in collections and one heretofore only known to occur over the higher portions of the plains lying to the eastward of the Rocky Mountains, in the States of Wyoming, Colorado, and New Mexico. This insect, as ascertained from inquiry, covered an area of about 400 square miles of territory in sufficient numbers to materially injure the grasses growing on the ranges of the entire region, and amongst these grasses the species of *Bouteloua* or Gramma grasses, and the Buffalo grass, *Buchloë dactyloides*. Grains and other culti-

> vated plants did not appear to be especially attractive to it. In fact very little or no injury was done by it to the cultivated crops growing within the region infested. . . . This year [1891] when the eggs hatched the young began to move from their breeding centers in all directions, seeking open places and the edges of plowed fields and following roadways. This trait of seeking open spots this season is probably due to the habit of the insect of naturally living on open ground, where grasses are short and scattering. The present year was very wet in this particular region and caused an undergrowth of grasses; hence the desire to find the natural conditions under which the insect lives. The young began moving, and finding these open places, congregated there. Having thus congregated, they must naturally feed, and they swept the grasses clean around these spots. So noticeable was this that, in certain spots where they had gathered about the hills of a species of ant which raises mounds of small gravel and cuts away the vegetation for some distance around them, they had enlarged these areas in some places for fully half an acre. This year Messrs. Snow and Popenoe observed them flying southward with such ease, by reason of their long wings, that they resembled birds.

When Bruner wrote this report *longipennis* had been known in the United States for 24 years. During that period it was thought of only as a rare, curious, harmless, strong-flying grasshopper of the western plains. The first recognition that the species might develop into one of economic importance came in Bruner's statement: "Imagine my surprise at finding here an entirely new insect as far as destructive locusts are concerned. Here in Colorado, and in immense numbers . . . the *Dissosteira longipennis* . . . covered an area of about 400 square miles of territory in sufficient numbers to materially injure the grasses growing on the ranges . . ."

E. A. Popenoe, an entomologist for the Department of Agriculture, apparently was on the scene of the outbreak in Colorado reported by the [Denver] Daily News (p. 17). An abstract of his report to the Association of Economic Entomologists stated *(68, p. 41)*:

> July 10 to 19 the author visited the northern part of Lincoln County, Colo., on account of newspaper reports of the stopping of trains by grasshoppers. He found a strip of country 16 by 25 or 30 miles in extent fairly covered with locusts, which proved to be *Dissosteira longipennis*. . . They were congregated especially in the boundaries of this area. The country is poor and planted here and there to corn and sorghum, and there are occasional patches of garden vegetation. The season has been favorable and cool. The locusts are said to have come in swarms from the south last fall and to have settled along the Big Sandy Creek in a patch two or three miles in circumference, in which they laid their eggs in great numbers. Upon hatching this spring the young spread outwards. At the time of his [the writer's] visit in the northern part of the strip the insects were in the last larval and pupal stages, with very few imagos. At the south line, however, the winged individuals were very abundant and flew like birds. . . .

Bruner, Popenoe, and the reporter for the Daily News were in close agreement on the size of the 1891 outbreak in Colorado. It apparently was restricted to one county and covered about 400 square miles or about 256,000 acres.

Herbert Osborn *(66)*, an agent for the Department of Agriculture, found *longipennis* in several counties in Kansas in 1891 but

not in outbreak numbers or giving evidence of soon attaining such proportions *(p. 55)*.

> *Dissosteira longipennis* was taken in some numbers at all points visited in Finney, Kearney, Hamilton, and Greeley Counties [Kansas], and as this species has caused so much injury in eastern Colorado this season, I took rather special pains to note its abundance and inquire as to any destruction resulting from it. At no point did it occur in destructive numbers, and I should not look for any injury from it in these localities in the near future at least.
>
> Most of those noticed were winged, some still fresh from the pupa stage. In general all the winged ones, when disturbed, moved southward, but nothing like a general migration was seen. . . .

In 1892 Vernon L. Kellogg *(52)*, of the University of Kansas, expressed an opinion *(pp. 43, 49)* similar to Osborn's concerning the economic importance of the species in Kansas.

> This locust, not until recently recognized as an injurious species, because of its comparative rarity, more nearly resembles the migratory locusts of the Old World than any other of our American forms. . . .
>
> The species while doing much damage in a restricted portion of eastern Colorado (400 square miles) last year, has not yet appeared in Kansas in serious numbers. . . .

Writing in 1891, Riley *(72, p. 424)* even expressed doubt whether the species was or ever would become migratory:

> This species, in size and length of wing, much more closely resembles the migratory and destructive species of Europe and some other countries than the Rocky Mountain Locust *(Caloptenus spretus)* and there seems to be no particular reason why, at times, it should not become destructive and fly in vast swarms from one locality to another. So far as past experience justifies calculation, however, it will not do so, and I think there is little reason to fear any continued or widespread injury from this species.

By 1893, Bruner *(16)* was beginning to take a different view, for by then he had found that the species showed a tendency to fly to new territory. He said *(pp. 36–38)*:

> Perhaps the greatest surprise to entomologists in the shape of injuries caused by locusts in this country was that occasioned during the past [1891] summer by the insect named above. Although it has been known to entomologists for twenty years, and has been twice described, this locust has been considered as belonging with our rarer representatives of the family of locusts. . . . *longipennis* is rather restricted in its range, being found only upon the plains of western Nebraska, Kansas, southeastern Wyoming, eastern Colorado, and northeastern New Mexico, at an elevation from 3,500 to 6,000 feet above sea level. . . .
>
> During the autumn of 1876, when the true Migratory Locust was passing over the eastern part of Nebraska, a large specimen of this long-winged 'hopper was seen to alight at West Point, in that State, where the writer was at the time engaged in hay-making. It was captured and shortly afterwards described as *Oedipoda nebrascensis*. This is the only record of the insect having been taken so far away from its native region as since ascertained. Several years later, August, 1881, while spending some time in the vicinity of Greeley, Colo., this species was very frequently met with both to the northward and southward of the town, upon the bench lands . . . Again, in 1889, while collecting specimens of various kinds in the extreme western part of Nebraska, a few individual specimens of this insect were taken, while, a year or two previously, it was obtained from

> Prof. F. W. Cragin, of the Washburn College, located at Topeka, Kans., who collected it in Barbour County, in that State.
>
> * * * * * * * * * * * *
>
> As would naturally be supposed, if we were to judge from the ample wings with which it is provided, this insect is an excellent flyer. It has shown a tendency to migrate during the past summer in Colorado, and is reported to have come into that region from the southward in 1890 prior to egg laying. . . .

1898

The outbreak in Colorado subsided after 1891, and there were no further reports of population increases in the State until 1898. During that period, however, the status of *longipennis* had altered, and entomologists were becoming alarmed by its demonstrated habit of migrating by flight, its changing food habits, and the extension of the area infested. Bruner *(20, pp. 126-127)* expressed this viewpoint when he wrote:

> Since that time [1891] the insect has been more or less numerous every year, and has found its way eastward almost to the Missouri river in Kansas and Nebraska. It has been quite destructive to crops of nearly all kinds in some parts of [Nebraska] and adjoining states, and has shown a tendency toward becoming a leading member among the list of destructive grasshoppers.
>
> During the past year, 1896, it was exceedingly abundant in the vicinity of Sidney, and did much harm to both small grain and corn crops, as well as to potato and other garden vegetation. Further south . . . it did not adhere as closely as formerly to the native grasses when choosing its food, nor did it seem to avoid entering the prairie vegetation as was its custom when first studied by me. In other words, this insect seems to be gradually changing its habits, and if the change continues to go on, we may look for it to be permanently a dreaded pest.

Bruner also reported *(19, p. 38)* that *longipennis* in 1896 had destroyed entire fields of small grain, some corn, potatoes, and gardens in the vicinity of Lodge Pole and Sidney Nebr. He expressed apprehension concerning its future economic importance. (See p. 3.)

No hint of the size or location of infested areas in 1898 has been found although authentic reports conclusively show that there were large areas infested with *longipennis* some place within its habitat during the spring and early summer. How, otherwise, could such hoards of flying grasshoppers have descended upon the city of Colorado Springs, Colo., as reported by Hunter *(45, p. 299)*:

> On the evening of July 21, this year, locusts came from the west down into Colorado Springs in countless numbers. Press reports stated "at some places they were in piles from 7 to 10 inches deep." Electric lights were not used for several evenings afterward to avoid attracting those passing over. Specimens sent by Board of Commerce of Colorado Springs to this department showed the invading species to be *Dissosteira longipennis*. Engineers running from Limon, Col., to Goodland, Kans., told the writer that night trains encountered locusts in great numbers on the tracks in the vicinity of Arriba, Col., from July 23d to 26th. It seemed evident that the rails by retaining heat longer at night than the earth attracted the insects. From the numbers of *Dissosteira longipennis* found about the engines coming into Goodland in the morning from the west, it is safe to say that the above was the predominant species.

The invasion of Colorado Springs was also described by Tucker *(97, pp. 112–113)*:

> Some years ago, while living in Colorado Springs, the business of insect collecting was one night unexpectedly forced upon me. A migration of locusts, the long-winged grasshopper, known as *Dissosteira longipennis* Thomas, was evidently detracted from flight over or near the city by the electric lights, directly after dark one evening, and the streets soon became covered with the living insects. In seeking every source of light, they invaded open places of business faster than they could be cleared away. They were caught in handfuls and flung into pails of scalding water to end their struggles. The sidewalks and street-crossings of several business blocks were covered so thickly that people walking there would crush a mass of bodies underfoot at every step. Next morning the street cleaners carted off dead grasshoppers by the wagon load, and for fear another invasion might come, the streets were not lighted for several nights afterward. This phenomenon occurred on Thursday evening, July 21, 1898; and the ridiculous part of the affair was the claim made in the daily papers that the insects came from Kansas, when, as a matter of fact, the species is more native to the Colorado plains.

Corkins *(28, p. 36)* gives additional information on Colorado Springs invasion in 1898:

> Mr. James P. Shearer kindly furnished us with the following notes on this outbreak:
>
> "I am pleased to be able to give you the exact date of the grasshopper scourge some years ago, which was on the night of July 1st, 1898, that being the night of my wedding. They were so bad at the corner of Pike's Peak and Tejon Streets that they stopped the street cars. The next morning they shoveled more than an ordinary express load of them out of our Pike's Peak entrance (to Perkins-Shearer Clothing Company store)".
>
> Mr. B. B. Reynolds, Superintendent of the Colorado Springs Water Department, who was serving on the City Fire Department at that time, recalls that the horses of the Department had to be roughshod to keep from slipping on the streets.

1899

The species occurred in local outbreak numbers some place in the general region of Goodland, Kans. in 1899 but again knowledge of the size of the infested area is lacking. S. J. Hunter *(46, pp. 16-17)*, entomologist for the University of Kansas, recorded his impression of the 1899 infestation of *longipennis*:

> Press reports having been sent out from Goodland concerning the prevalence of grasshoppers along the railroad, their numbers being reported such as to interfere with the action of the drive wheels upon the rails, I decided to go out and investigate. . . . I found [from examination of cowcatchers on railroad engines] the species which were most common there to be the long-winged locust, *Dissosteira longipennis*, the Carolina locust, *Dissosteira carolina*, and the yellow locust, *Melanoplus differentialis*. . . .

1900

A local outbreak of the species must have occurred some place near the southwestern extremity of its habitat in 1900 when Smith *(87, p. 3)* reported that "In 1900 this insect invaded the town of Las Vegas, N. Mex., in great numbers and crushed specimens were everywhere seen on the sidewalks."

1901

The species was present in 1901 in unusual numbers in southwestern Nebraska, but apparently was of minor importance elsewhere *(23)*: "*Dissosteira longipennis* Thos. . . . not nearly so abundant as it was 4 or 5 years ago."—*(p. 48)*. However, "At McCook, Nebr., [southwestern Nebr.] August 9, we collected some thirty-odd pieces [species] of the native grasshoppers, which abound in this vicinity. . . . Among the . . . species which existed in unusually large numbers [was] *Dissosteira longipennis* . . ." — *(p. 40)*.

1913

Other local outbreaks, after that of 1891, must have been comparatively small, for the extent of the territory infested has not been recorded. However, in 1913, in Roosevelt County, N. Mex., another local outbreak occurred that was similar in size and intensity to that in Colorado in 1891.

Again, after the seriousness of the situation had been reported by local residents to the Department of Agriculture, the Bureau of Entomology dispatched an entomologist, Harrison E. Smith, to ascertain the facts and to give assistance.

The 1913 outbreak originated from grasshoppers that had flown into Roosevelt County and deposited their eggs the previous fall. Smith *(87, p. 3)* found that:

> The 1913 outbreak [in Roosevelt County, N. Mex.] of this species extended over 400 to 500 square miles, the prairie grasses, grain, and garden crops within this area being in great part devastated. Herds of cattle usually grazing within this infested area were forced to travel from 11 to 13 miles for grazing facilities, and would return to their usual watering places only at intervals, varying from 24 to 56 hours. Freight and passenger trains were repeatedly stopped by grasshoppers massing upon the railroad tracks, this being frequent from the middle of May until the first of July.
>
> The prairie grasses within the infested area were so completely ravaged that hardly a surface depression of the soil could be located which was not from one-fourth to completely filled with grasshoppers' droppings.

The infested area was mainly from the town of Elida southwestward about 6½ miles and northwestward about 10 miles *(87)*. Albert Tillinghast, who lived in the midst of the 1913 outbreak, was interviewed at his ranch in February 1952. He lives on the same ranch his father homesteaded, and vividly remembers the 1913 outbreak which occurred when he was 16 years old. His ranch was in about the center, north and south, of the band of *longipennis* that migrated in a general eastward direction in 1913. He said that the band of grasshoppers was from ¾ to 1½ miles wide, and that it continued migrating through his father's ranch for 3 weeks. The grasshoppers "completely destroyed everything green in their path, ate corn and garden crops clear into the ground, and completely cleaned the bark from cedar fence posts."

Mr. Tillinghast remembers nymphs as being about ½ to ¾ inch long when they were migrating through his ranch. They completely covered the surface of the ground and he compared their

surging movements to waves or ripples in a grain field. He described the difficulty when driving or riding of forcing horses into the dense band, and told how the mashed nymphs balled up like thick mud on the buggy wheels and horses' hoofs.

He said that when migrating nymphs diagonally encountered the right-of-way of the Santa Fe Railroad about 1 mile northwest of his ranchhouse, they piled up against the track and some of them changed direction somewhat so they followed along the track. They forced the railroad to break its westbound freight trains into 3 sections and, from his ranch to Toreno station, to pull each section with 2 engines. Toreno is the high point on the railroad between the Brazos and the Pecos watersheds. For about 3 weeks the extra engine was used as a helper. He said that day after day and night after night, with both engines putting out all the sand they could, he would hear the engines chuffing away, wheels spinning on rails made greasy-slick by the mashed bodies of countless numbers of grasshoppers.

The grade appears moderate to a casual observer, but sometimes it required 2 hours for train sections to negotiate the 2 miles from the Tillinghast ranch to Toreno.

Mrs. Eulia Swaggerty of Elida remembers the invasion when it reached her father's ranch at the east end of town. The grasshoppers had destroyed nearly everything green as they passed through town, but the ferocity of their attack was by that time abating. Her father saved most of his 40-acre grain field by plowing furrows all around it. Most of the pests followed the furrows, and not much damage was done by those that crossed into the field. She remembers the grasshoppers continuing their march eastward past her father's ranch but in much lesser numbers than had devastated the countryside west of town.

The 1913 outbreak in New Mexico apparently subsided without giving rise to a greater outbreak the following year in that area or elsewhere.

1921

The next we know of *longipennis* reaching alarming populations was in 1921 when it went on a rampage in Colorado. Subsequently it was learned that, unreported, the infestation had been building up and spreading in the outbreak area for about 2 years. Corkins *(28, p. 36)* described this outbreak:

> The swarm of locusts which caused the infestation in 1921 originated in the low land adobe flats in northwestern Crowley County. . . . Here, under natural conditions, the swarm had increased in numbers for 2 years, according to residents, with no alarm being felt.
>
> The infestation of 1921 began migrating toward the highlands, moving in an army-like front 42 miles long and averaging 1½ miles deep. In thickness, the 'hoppers varied from 50 to 200 per square foot. Figuring on this basis, the actual infestation of nymphs was 40,320 acres at one time. . . .

Presumably, nymphs in the 1921 infestation spread from Crowley County, Colo., into the adjacent portions of three other counties,

for Corkins acknowledged services rendered by county agents of El Paso, Pueblo, and Lincoln Counties in quelling the outbreak.

1934

The next outbreak was in Lincoln County, Colo. The State Extension Entomologist *(34*)* assisted the county agent in organizing to fight the grasshoppers that infested 700 square miles of land. This outbreak persisted until 1940. Increase and decrease of the infestation from 1933 to 1940 is shown in figure 4.

1936

Between the summers of 1934 and 1936, populations of *longipennis* had built up extensively some place within its range, for Sam C. McCampbell reported *(35*)* that by mid-August 1936, thousands of acres of winter pasture had been destroyed in Colorado. This damage was caused mainly by adults that flew into 10 southeastern counties of the State.

> This season's losses from *longipennis* [in Colorado] were practically unavoidable. The major invasion of the State did not take place until after the first of August. . . . The infestation . . . extends about 125 miles north from the New Mexico and Oklahoma line and about 75 miles west from the Kansas line. This vast area could not be surveyed intensively. County agents and ranchers assisted in locating areas on which flight 'hoppers had settled. The result was that almost 2,000,000 acres were located as 'hopper landing fields. Of this area, the amount that actually is infested is largely a guess.

Parker and Shotwell *(49*)* said "In Colorado, *Dissosteira longipennis* was numerous and dominant in a large part of the rangeland in the southeastern quarter."

D. longipennis was of no economic importance in Kansas in 1936 but it was mentioned a few times in the fall survey *(61*)*. It was recorded only in Union County, N. Mex., and in Cimarron and Texas Counties, Okla. It was not recorded in Texas.

1937

In his 1937 reports *(37** and *38*)* McCampbell estimated that 3,400,000 acres of land in Colorado had been infested with *longipennis* just after egg-hatching time: "In 1937, egg beds have been found in large numbers in 11 counties and smaller numbers in 2 other counties. . . . Much of the area that is infested with *longipennis* eggs has never been recorded before as egg beds of the species."

Some indication that the species was increasing throughout its range is to be found by comparing the number of times it was collected in each of the five States in 1936 and in 1937. These comparisons are valid only as trends, because the interest aroused by the necessity for large-scale control in 1937 stimulated increased effort to find the species when workers made the fall survey. Comparisons of the number of times the species was collected *(61*, 62*)* in each State each year are given:

	1936	1937
Colorado	1	1,114
Kansas	0	26
New Mexico	0	136
Oklahoma	0	31
Texas	0	10

1938

The area infested in the spring of 1938 in Colorado, determined by the 1937 fall survey *(37*, 38*)* was 4,026,000 acres. W. M. Ginn *(13*, 14*)* of the New Mexico State College, stated: "The southern third of Union County, the southern and eastern borders of Colfax County, the northern borders of Harding and Quay Counties, and the northeastern tip of Mora County contain quantities of *longipennis* egg beds."

From Ginn's reports it is estimated that approximately 1 million acres of rangeland in New Mexico was infested in 1938. The county agent of Union County estimated *(19*)* that over 1,870,000 acres were included in the area that grasshoppers had damaged considerably during the spring and summer.

Kelly *(27*)* said: "*D. longipennis* was plentiful in western [Kansas] counties on the wing."

The species was present, but of little importance, in the Panhandle counties of Oklahoma and Texas as evidenced in reports: ". . . there was practically no damage in the Panhandle counties [Oklahoma] until late in the season when *Dissosteira longipennis* flew in from some other part of the country. . . . Around July 20, the first flights . . . were observed in Cimarron County. Later flights occurred almost daily and continued on up to September 1. . . . At present this species is pretty generally distributed throughout the Panhandle counties as far east as Beaver."—*(75*)*. "*Dissosteira longipennis* was destructive in the northwestern part of the Texas Panhandle. They did not seriously invade territory that was free from grasshoppers earlier in the season."—*(5*)*.

No estimate of the area infested in Texas in 1938 has been found, but of the 1,222,830 acres of range and pasture land that was baited *(5*)* approximately one-half, or 687,000 acres, was for control of *longipennis*.

1939

The fall survey of 1938 indicated that about 4,600,000 acres in 13 southeastern Colorado counties would be infested with the High Plains grasshopper in 1939 *(40*)*.

According to Spain *(71*, 72*)*, the nymphs in Kansas in 1939 did not band together or migrate in characteristic manner, and Kelly *(28*)* said: "*D. Longipennis* laid few eggs in southwest Kansas in 1938 but was not a pest [in 1939] at any time. No egg beds were found in either the fall or spring surveys. Nymphal
pulations in several pastures [1939] of Stanton and Stevens
unties indicated there may have been a few light concentrated
g beds."

The 1938 fall survey in New Mexico, reported by Landrum *(66*)*, indicated 1,206,000 acres would be infested in 1939.

According to the Oklahoma State leader of grasshopper control, *longipennis* was not dominant in any county in that State in 1939 *(76*)*, but from the estimate of bait needed to control the species it was deduced *(68*)* that 50,000 acres would be infested.

The Federal supervisor in charge of control in New Mexico, Oklahoma, and Texas in 1939 estimated *(6*)* that 6,835,000 acres were infested that year in the 3 States.

1940

The 1939 fall survey showed that about 30,000 acres of range would be infested with the High Plains grasshopper in 1940 in New Mexico *(7*)* and about 164,000 acres in Colorado *(3*)*.

RANGE AND DESCRIPTION OF SPECIES

Range

Dissosteira longipennis is a native of the High Plains in the United States and is not known to occur elsewhere in the world. Willard D. Johnson *(50)* described the High Plains as a topographic unit, and mapped it as an area comprising in the main eastern Colorado, southwestern Nebraska, western Kansas, the Panhandles of Oklahoma and Texas and an area in these States to the east, and eastern New Mexico. (See fig. 5.)

Description

The species was studied, first described, and named *Oedipoda longipennis* by Cyrus Thomas from specimens collected in Kansas in 1872 by an expedition of the U. S. Geological Survey *(93)*. It previously had been collected in Colorado in 1867 by C. V. Riley *(72, p. 423)*, who said, "This species always occurs in that section [eastern Colorado], and some of the first insects which I collected in Colorado on my first visit in 1867 were of this species, and are now in the National [Museum] Collection."

The type specimen of the species is in the collection of the U. S. National Museum, Washington, D. C., and bears the broad general label, "Kansas, Collection of C. V. Riley." This collection includes many specimens that may or may not have been collected by Riley. They have been incorporated into the museum collection.

The original description of the species *(93, pp. 463–464)* is as follows:

> *OE. longipennis*, nov. sp.
>
> Elytra and wings longer than the body; the elytra spotted; the wings black or dark fuliginous at the base.
>
> *Male.*—The vertex not very broad; central foveola elongate elliptical, with a slight median raised line, and open in front; frontal costa rather narrow, slightly expanded at the ocellus, sulcate, not expanding below. Median carina of the pronotum prominent, sub-cristate, as in *OE. Carolina*, cut near the middle by the posterior transverse incision, each part arcuate; anterior margin somewhat angled, and

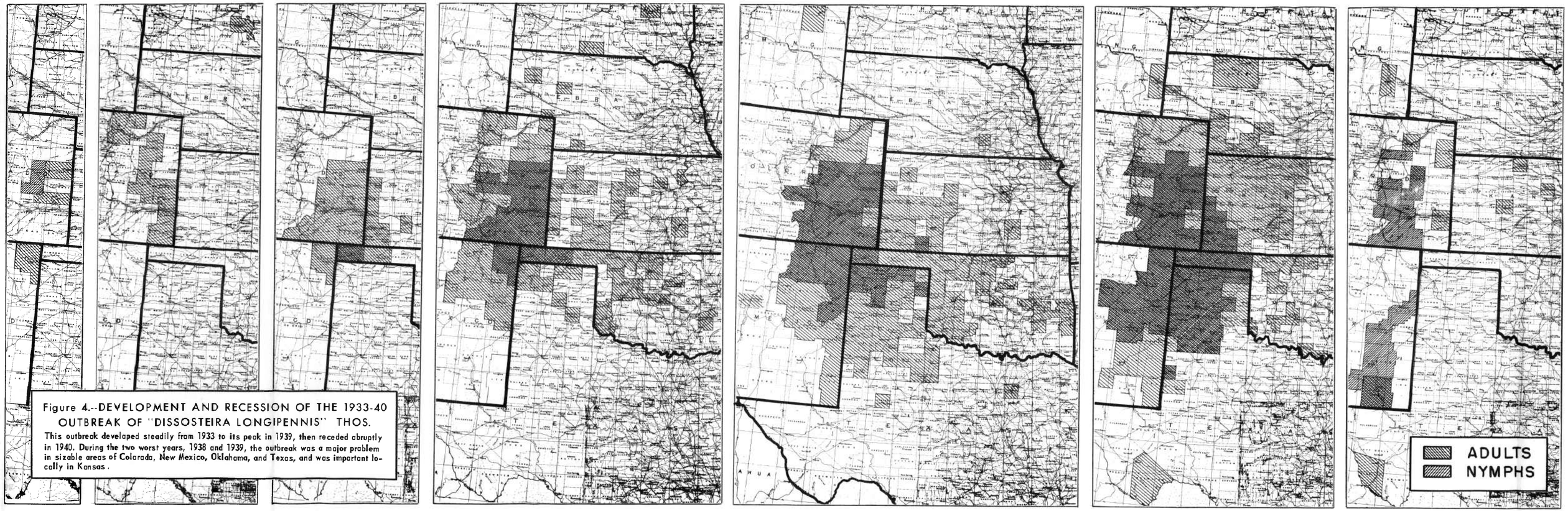
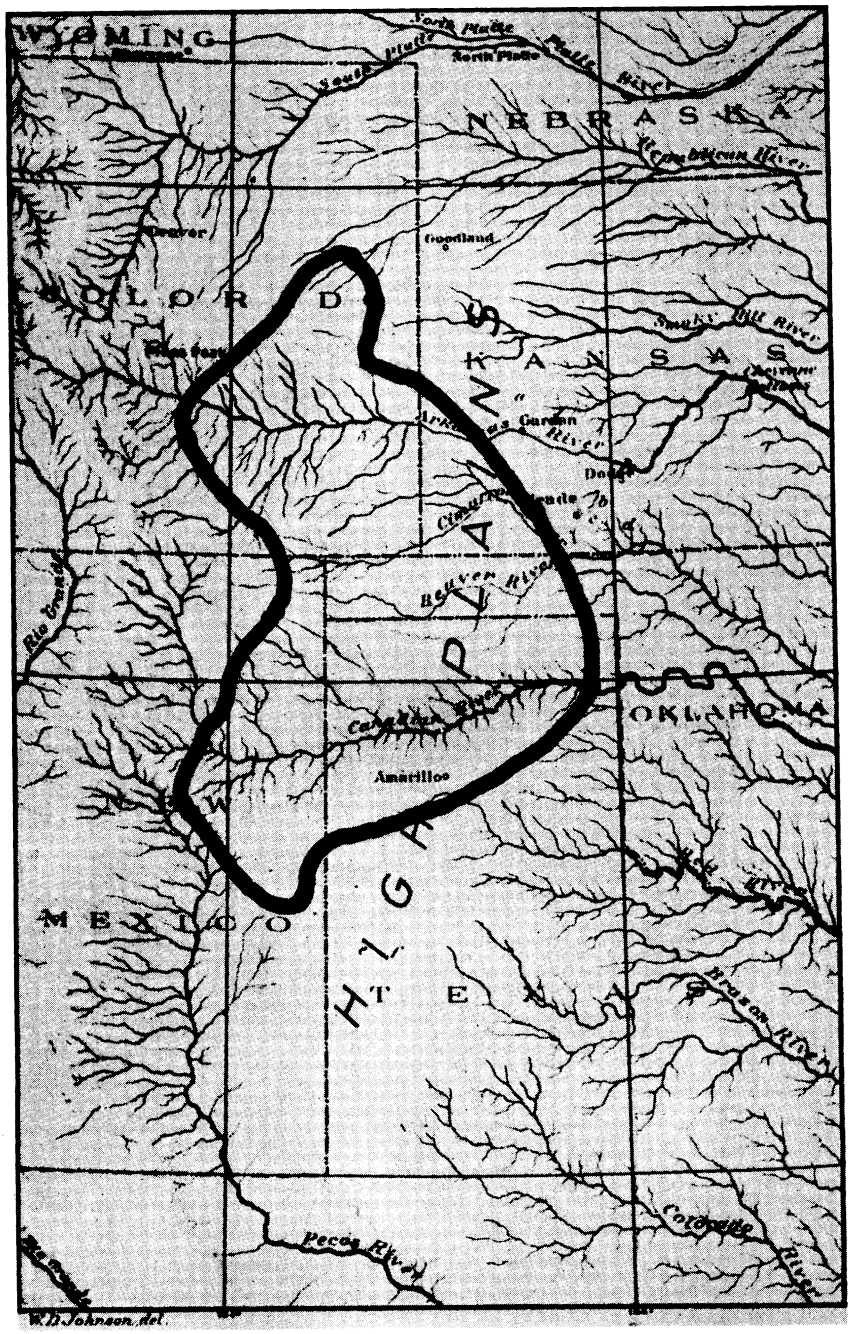


Figure 4.--DEVELOPMENT AND RECESSION OF THE 1933-40 OUTBREAK OF "DISSOSTEIRA LONGIPENNIS" THOS.

This outbreak developed steadily from 1933 to its peak in 1939, then receded abruptly in 1940. During the two worst years, 1938 and 1939, the outbreak was a major problem in sizable areas of Colorado, New Mexico, Oklahoma, and Texas, and was important locally in Kansas.



BN—1928

FIGURE 5.—The High Plains, as mapped by Willard D. Johnson *(50)*. Habitat area of *longipennis* outlined.

extending slightly on the occiput; the posterior extremity acutely and rather sharply angled; the disk of the posterior lobe smooth and apparently without punctures. The elytra narrow, remarkably straight, the margins parallel; longer than the entire body. Wings about the same length, and broad. The posterior femora not channeled beneath. The cerci rather long, subcylindrical, and terrete. Antennae passing the thorax.

Color, (dried after long immersion in alcohol.)—Reddish yellow. The head and pronotum, especially the dorsal portions, pale reddish, dotted with pale brown. The basal portion of the elytra reddish-yellow, the apical portion pellucid; marked throughout with dark brown spots somewhat in the form of bands. The wings for a very small space around the immediate base are transparent yellow; a triangular space at the apex extending inward about one-third of the way to the base pellucid, sprinkled at the immediate apex with fuscous dots; the posterior margin has a narrow pellucid rim; the rest is of a dark fuliginous color, which, when the wing is fully spread, appears like a very broad band across the basal two-thirds, with its outer border parallel to the body. The posterior femora have two oblique brownish bands on the external face; within are two black bands; apex black internally. Venter and pectus dull yellowish-white. Antennae pale at base; apical portion dusky.

Dimensions.—Length, 1.14 inches; elytra, 1.25 inches; posterior femora, .64 inch; posterior tibiae, .55 inch.

Found among the collections submitted to me from the Agricultural Department, marked Kansas, which, from the other specimens, I suppose to be correct. The species is somewhat remarkable, and quite different from any other one belonging to the United States which I have seen. The dark wing would appear to bring it near *Carolina* and *Carlingiana,* but while it approaches the former in its slender form, it is nevertheless very distinct. I have never met with it at any point in the West, nor have I seen it in any other western collection. On this account, added to that of its semitropical *look,* (this word conveys my idea better than a long sentence), I am inclined to believe it is a southern species, and may be found in the Indian Territory or Texas.

SCIENTIFIC AND COMMON NAMES

Scientific Names

In 1876 Samuel H. Scudder *(75)* proposed Dissosteira as a new genus, in which he grouped *Oedipoda longipennis* Thos. and *Gryllus carolina* L. and designated the latter species as the genotype.

Lawrence Bruner *(9),* from a single specimen which had alighted in a hayfield at West Point, Nebr., in August 1876, described a new species which he named *Oedipoda nebrascensis* n. s. At that time he apparently was either unaware of Thomas' original description or did not recognize *Oe. longipennis* and *Oe. nebrascensis* as two different names for single species. He may have been yet unacquainted with Scudder's proposal of a new genus.

The original description by Thomas was based on a study of a male specimen and included the statement "Female unknown." Although Bruner's description was of a female, he indicated *(16, p. 38)* that he had later studied both sexes, in differentiating between males and females as follows:

> Length of body—male, 28.5^{mm}, female, 43^{mm}; of tegmina—male, 31.5^{mm}, female, 47^{mm}; of posterior femora—male, 16^{mm}, female, 21^{mm}; spread of wings—male, 67^{mm}, female, 100^{mm}.

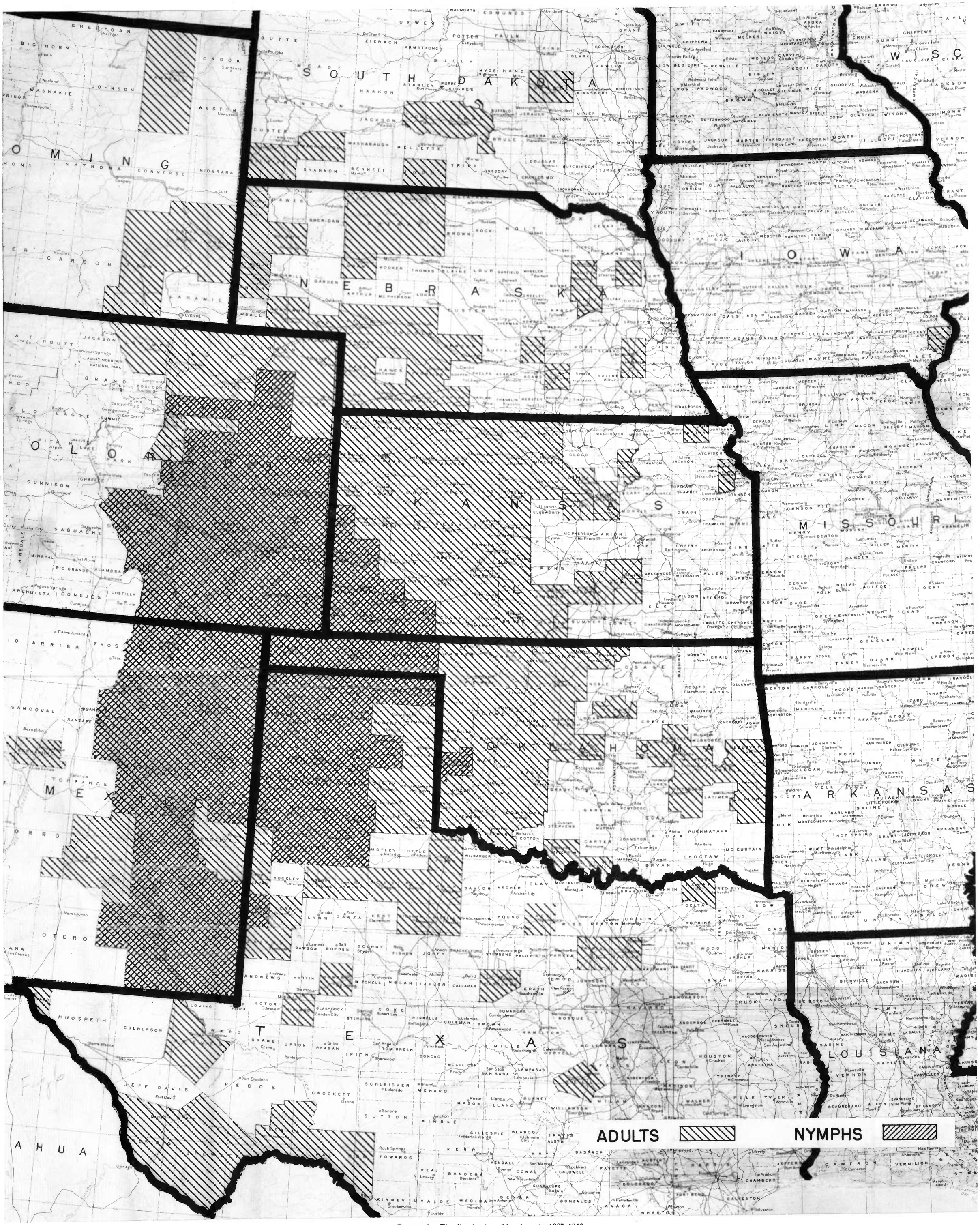


FIGURE 6.—The distribution of longipennis, 1867–1956

In 1883 Bruner referred to the species as *Oedipoda longipennis (11, p. 54)* but listed it *(p. 57)* as *Dissosteria [Dissosteira] longipennis,* indicating his possible acceptance of Scudder's proposal for a change in generic name. C. V. Riley *(70)* indicated in 1884 that he was turning toward the acceptance of the generic name *Dissosteira* when he wrote of *"Oedipoda (Dissosteria) longipennis."* Both Bruner and Riley had completely accepted Scudder's proposal by 1891, for then they were publishing accounts referring to the species as *Dissosteira longipennis (13, 71),* the name which is in use today.

Common Names

Several common names have been used for *Dissosteira longipennis.* Among these are "long-winged locust" *(13, 14),* "long-winged locust of the plains" *(16, 20),* "long-winged plains locust" *(19),* "long-winged grasshopper" *(87),* and "long-winged grasshopper of the plains" *(33).* When the species was in extensive outbreak numbers during the period 1937–40, it was generally referred to in the press as the "migratory grasshopper," and many ranchers and others called it the "migratory grasshopper of the plains," the "long-winged migratory grasshopper," or the "long-winged migratory grasshopper of the plains." The American Association of Economic Entomologists *(65)* in 1949 approved the common name "long-winged plains grasshopper." Since its native home is restricted to the High Plains, which constitutes only a small portion of the Great Plains and other long-winged species occur in the plains area, the Entomological Society of America in 1954 approved the common name "High Plains grasshopper" *(73a, p. 8).*

DISTRIBUTION

In this publication, "distribution" denotes only the geographical location at which a specimen has been collected; "habitat" refers to the natural region that *longipennis* inhabits.

All the locations found in this study where the species has been collected or authentically reported are listed in Distribution Records, pages 32 to 55.

The known distribution of *longipennis* is shown in figure 6. This map is a composite picture of all counties in which the species has been recorded during the period 1867–1957. It has no reference to the severity of an infestation in a particular county or to the number of times the species may have been found there.

The occasional invasion of fringe counties is a "spill-over" brought about by the insects marching or flying out of nearby heavily populated areas within its habitat. Adults are strong fliers Invasions of counties remote from the habitat of the species undoubtedly are by flights that occur mainly during periods when the species has developed to outbreak proportions within its habitat. Adults collected as far away as Beadle County, S. Dak.,

and Des Moines County, Iowa, 450 miles and 750 miles, respectively, from the nearest part of the habitat, probably reached there by flying.

Whether adults of the High Plains grasshopper reach remote points by sustained flights or by a series of shorter ones is not known. In areas where adults have been collected oftenest and in greatest numbers outside of the habitat, flight probably is a combination of both. Flight outside of the habitat generally has been in a northeasterly direction. The species is not known to have invaded any areas west of the Continental Divide.

Entomologists of the Colorado Agricultural Experiment Station *(40*)* liberated 2,940 marked adults in 1938 at several points within the State. Seventeen adults that the workers believed to be among those originally marked were later recaptured. These captures showed that, from the point of liberation, 3 adults had flown 16 miles, 2 had flown 50 miles, 3 had flown 60 miles, 1 had flown 75 miles, 3 had flown 110 miles, 2 had flown 125 miles, 2 had flown 140 miles, and 1 had flown 175 miles. Whether the distances covered were in one sustained flight or in a series of short flights was not ascertained.

Proof that the High Plains grasshopper makes massed flights that carry it long distances is ample. Why it does is largely a matter of speculation, for research directed toward making that determination has not been conducted. Factors influencing flight, as observed in survey and control work in the field, are discussed under the heading "Biology."

When he first described the species, Cyrus Thomas *(93, p. 464)* believed it had very limited distribution. He said, "I have never met with it at any point in the West, nor have I seen it in any other western collection." The species was collected in 1867 *(72)* in Colorado, and in 1876 *(16)* in Cuming County, Nebr., near the eastern boundary of the State. Colorado and Kansas by 1884 had been included in the areas in which the species was distributed, for C. V. Riley *(70, p. 202)* spoke of *"Oedipoda (Dissosteria) longipennis,* which is met with on the plains of Colorado and Kansas . . ." During the same year Saussure *(74)* listed it as occurring in Kansas and Texas.

With the passing of years, the area in which the species was known to exist expanded until by 1891 Bruner *(68, p. 41)* reported it to include Nebraska, Kansas, Colorado, Wyoming, and northeastern New Mexico. Bruner said in 1893 *(16, pp. 36–37) "longipennis* is rather restricted in its range, being found only upon the plains of western Nebraska, Kansas, southeastern Wyoming, eastern Colorado, and northeastern New Mexico, at an elevation of from 3,500 to 6,000 feet above sea level."

By 1896 this grasshopper was known *(19, p. 38)* in "portions of the high prairies lying between the upper Niobrara and North Platte, between the latter and the South Platte, between this and the Republican, and southward to beyond the Arkansas into northeastern New Mexico. It extends from the vicinity of the one hundred and first meridian on the east to the base of the Rocky Mountains, and occasionally drifts eastward with the winds in considerable numbers even to Lincoln, Nebr."

Several of the publications studied include Idaho and Montana in the area in which *longipennis* had been collected. Speaking of Idaho, Robert Milliken *(63, p. 19)* in 1893 said, "There are several species of locusts to be found in the infested fields . . . [including] quite a sprinkling of *Dissosteira longipennis* and *D. carolina.*" In the "Catalogue of the Described Orthoptera of the United States and Canada" *(76)*, *longipennis* is shown as occurring (1900) in Idaho and Montana. Habitat (1905) is given in the "Biologia Centrali-Americana, Acridiidae," in vol. 2 of "Orthoptera" *(24, p. 163)* as "North America—Idaho and Montana to Texas and New Mexico." Distribution, as discussed in "The Grasshopper Outbreak in New Mexico During the Summer of 1913" *(87)*, includes the State of Idaho.

Since this study has produced no authentic record that the species was ever collected in either Idaho or Montana, it is concluded that several errors that have crept into the literature have been accepted as facts. Milliken's report must have been a case of erroneous identification, for though there have been repeated surveys since 1893, the species has not been captured or reported in Idaho.

Regardless of extreme care taken in the search for information on distribution, the possibility remains that certain collection records may be overlooked because they do not appear in published form. In 1929 *longipennis* was collected by E. R. Tinkham in Presidio County, Tex. He wrote *(96, p. 586)*: "the Marfa records are a considerable extension southward of the known range of this species and hence are the first from southwestern Texas." The present study has found that the species was collected by Rehn and Hebard in 1912 in Reeves, Terrell, and Val Verde Counties, Tex. *(16*)*, and by Poling in Presidio County, Tex., in 1925 *(17*)*. In the Distribution Records (p. 32), the person named is the one who collected the species. In a few instances where the collector is unknown, the person who determined the specimens, searched the species out in museum collections, or published on it is named.

The list of distribution records was prepared from bulletins, entomological magazines, insect collections, processed survey reports, typewritten or mimeographed grasshopper survey or control reports, and so forth. Prior to the general outbreak of 1933–40 there were few records; all those found are included in the list. After the species had caused damage, focusing widespread attention on it, records became quite voluminous and many repetitions occurred. For example, *longipennis* was reported many times in a single county in a single year when survey and control reports were made by personnel of the Bureau of Entomology and Plant Quarantine, both weekly and annually. Other records were made by entomologists hired in various capacities by the States. Duplications were avoided as far as consistent with the showing of participation by each cooperating agency.

Distribution records are incomplete. Before *longipennis* became economically important, it was recorded only rarely by a few individuals who had taken it on exploration or insect-collection

expeditions. After it had been recognized as injurious to range and planted crops, it became an insect of potential economic importance and as such attracted the attention of entomologists generally. Records of distribution increased in proportion to this increased interest. From 1933 to 1936, when a general outbreak was developing, records of distribution of *longipennis* did not keep pace with the acceleration in the increase and spread of the species. During that period it often was not recorded by State and Federal men who made surveys because usually only the dominant species and the one next in importance, in numbers, were recorded. When, in 1936, it was recognized that a general outbreak was impending, special surveys were conducted to determine the extent of the infestation and to provide information that could serve as a basis for planning control. Special surveys were continued through the season of 1940 to provide information necessary for control operations and appraisal of results. Through the years 1941–55 limited surveys in habitat areas were made for the purpose of detecting local population buildups, if they occurred, before they could reach outbreak proportions. During that period no such buildups were found. Indeed, only a few single specimens were seen and those but rarely.

Distribution Records

Year	State and county		Reference or collector[1]
1867	Colorado		Riley *(72)*
1872	Kansas		*(93)*
1875	Colorado:	El Paso	Uhler *(87)*
1876	Nebraska:	Cuming	Bruner *(16)*
1877	Colorado:	El Paso	Uhler *(99)*
	Kansas:	Kearny	*(15*)*, *(17*)*
1881	Colorado:	Weld	Bruner *(17*)*
1887	Kansas:	Barber	*(17*)*
1889	Kansas:	Barber	Cragin *(17*)*
1890	Colorado:	Lincoln	Popenoe *(68)*, egg and adult
1891	Colorado:	Lincoln	Bruner *(14)*, nymph
			Popenoe *(68)*, nymph and adult
		Washington	Bruner *(14)*, nymph and adult
			Popenoe *(16*)*
	Kansas:	Finney	Bruner *(14)*
		Greeley	Bruner *(14)*, Riley *(15*)*, Osborn *(66)*
		Hamilton	Osborn *(66)*, Bruner *(14)*, Riley *(15*)*

[1]Where no stage is indicated only adults were collected. (F) and (S) indicate fall or spring observation.

Year	State and county		Reference or collector
		Kearny	Bruner *(14)*, Osborn *(52)*
	Nebraska:	Hall	Bruner *(17)*
1892	Kansas:	Finney	Kellogg *(53)*
		Hamilton	Kellogg *(53)*
		Sedgwick	Tucker *(26*)*
	Nebraska:	Cuming	Bruner *(17)*
		Hall	Bruner *(17)*
		Lancaster	Bruner *(17)*
		Madison	Bruner *(17)*
		Platte	Bruner *(17)*
	South Dakota:	Fall River	Bruner *(17)*
1894	Colorado:	Washington	*(15*)*
		Yuma	*(15*)*
1895	Nebraska:	Cheyenne	Raymond and Moffitt *(18*)*
		Lancaster	*(16*)*
1896	Kansas:	Riley	*(70*)*
		Cheyenne	Bruner *(20)*
	Nebraska:	Deuel	*(18*)*
1897	Kansas:	Douglas	Hunter *(44)*
	Nebraska:	Cheyenne	Hunter *(48)*
		Keith	Hunter *(48)*
		Lincoln	Hunter *(48)*
1898	Colorado:	El Paso	Hunter *(45)*, *(48)*
		Prowers	*(15*)*
	Kansas:	Edwards	Hunter *(44)*, *(87)*, egg and adult
		Douglas	Hunter *(44)*
1899	Kansas:	Sherman	Hunter *(46)*
1900	New Mexico:	San Miguel	Smith *(87)*
			Scudder and Cockerell *(77)*
1901	Colorado:	Larimer	Dyer and Caudell *(15*)*
		Otero	*(45*)*
		Pueblo	*(16*)*
	Nebraska:	Dundy	Bruner *(18*)*
		Redwillow	Carriker *(18*)*, Bruner *(23)*
	New Mexico:	Lincoln	Townsend *(77)*
		San Miguel	Blake, Cockerell *(77)*
		Union	Bruner *(77)*
	Oklahoma:	Payne	Caudiff *(25)*
1904	Colorado:	Bent	Gillette *(38)*
		Denver	Gillette *(38)*, Rehn and Hebard *(69)*
		El Paso	Hebard *(16*)*, Gillette *(38)*
		Fremont	Gillette *(38)*

Year	State and county		Reference or collector
1904	Colorado:	Larimer	Gillette *(38)*, Rehn and Hebard *(69)*
		Logan	Gillette *(38)*
		Morgan	Gillette *(38)*, Rehn and Hebard *(69)*
		Otero	Gillette *(38)*, Rehn and Hebard *(69)*
		Prowers	Gillette *(38)*
		Pueblo	Gillette *(38)*
		Washington	Gillette *(38)*
		Weld	Gillette *(38)*
	Nebraska:	Cheyenne	Rehn and Hebard *(69)*
1905	Oklahoma:	Kiowa	Morse *(15*)*
	Texas:	Hardeman	Morse *(15*)*
		Donley	Morse *(17*)*
		Potter	Morse *(17*)*
1911	Kansas:	Meade	Williams *(16*)*
		Stanton	Williams *(16*)*
		Stevens	Williams *(16*)*
1912	Kansas:	Osborne	Williams *(16*)*
		Trego	Williams *(26*)*
	New Mexico:	Chaves	*(15*)*
	Texas:	Bell	Rehn and Hebard *(16*)*
		Eastland	Rehn and Hebard *(16*)*
		Midland	Rehn and Hebard *(16*)*
		Reeves	Rehn and Hebard *(16*)*
		Tarrant	Rehn and Hebard *(16*)*
		Terrell	Rehn and Hebard *(16*)*
		Val Verde	Rehn and Hebard *(16*)*
1913	New Mexico:	Curry	Smith *(87)*
		Roosevelt	Smith *(87)*, nymph and adult
1914	Colorado:	Otero	*(15*)*
1915	Colorado:	El Paso	Baker *(16*)*
	Nebraska:	Lancaster	Partridge *(18*)*
	New Mexico:	Sandoval	Woodgate *(14*)*
1916	Kansas:	Barber	Beamer *(16*)*
		Wilson	Beamer *(16*)*
		Rush	*(17*)*
1917	Oklahoma	Cimarron	Fenton *(35)*
1918	Kansas:	Comanche	Hubbell and Ortenburger *(43)*
	Oklahoma:	Comanche	Hubbell and Ortenburger *(43)*

Year	State and county		Reference or collector
			Hubbell *(17*)*
1919	Colorado:	Bent	Rehn and Hebard *(16*)*
		Las Animas	Rehn and Hebard *(16*)*
		Otero	Rehn and Hebard *(16*)*
	Nebraska:	Redwillow	Morse *(17*)*
	Kansas:	Rush	*(17*)*
	South Dakota:	Jones	Severin *(58*)*, Hebard *(39)*
1921	Colorado:	Crowley	Corkins *(28)*, nymph and adult
		El Paso	Corkins *(28)*
		Lincoln	Corkins *(28)*, nymph and adult
		Pueblo	Corkins *(28)*, nymph and adult
			Rehn and Hebard *(16*)*
	Kansas:	Hamilton	Rehn *(16*)*
		Thomas	Ortenburger *(17*)*
	New Mexico:	Colfax	Rehn *(16*)*
		Roosevelt	Rehn and Hebard *(16*)*
	Oklahoma:	Texas	Rehn *(16*)*
	Texas:	Childress	Rehn *(16*)*
		Lubbock	Rehn and Hebard *(16*)*
		Potter	Hebard *(16*)*
1925	Kansas:	Sherman	Beamer *(16*)*
	Texas:	Presidio	Poling *(17*)*
		Jack	Baker *(17*)*
1926	Oklahoma:	Beckham	Remie *(17*)*, nymph
		Cimarron	Hubbell, Remie *(17*)*
		Harmon	Hubbell *(17*)*
		Texas	Remie *(17*)*, nymph
			Hubbell *(17*)*
	Texas:	Lubbock	Little *(51*)*
		Terry	Little *(51*)*
1929	Texas:	Presidio	Tinkham *(96)*
1930	Oklahoma:	Woods	Bird *(17*)*
	Texas:	Presidio	Tinkham *(96)*
1932	Oklahoma:	Cimarron	*(16*)*, Shotwell *(5*)*
		Texas	Stiles *(77*)*
	Texas:	Lipscomb	Isely *(16*)*
1933	Colorado:	Kiowa	Rodeck and James *(1*)*
		Kit Carson	Rodeck and James *(1*)*
1934	Colorado:	Lincoln	McCampbell *(33*)*, egg (S) and nymph
	New Mexico:	Union	Eyer and Steward *(9*)*

Year	State and county		Reference or collector
1935	Colorado:	Arapahoe	Mickle *(59*)*
		Baca	Mickle *(59*)*, egg (F) and adult
		Cheyenne	Mickle *(59*)*
		Denver	Mickle *(60*)*
		Kiowa	Mickle *(59*)*
		Lincoln	Mickle *(60*)*
		Prowers	Mickle *(59*)*
		Washington	Mickle *(60*)*
		Weld	Mickle *(59*)* egg (F) and adult
	Oklahoma:	Beaver	Forgan and Hubbell *(17*)*
	South Dakota:	Lyman	Peterson *(60*)*
	Texas:	El Paso	*(51*)*
		Lamar	*(51*)*
1936	Colorado:	Baca	McCampbell *(36*)*, egg (F) and adult
		Bent	McCampbell *(36*)*, egg (F) and adult
		Cheyenne	McCampbell *(36*)*, egg (F) and adult
		Crowley	McCampbell *(36*)*
		Kiowa	McCampbell *(36*)*, egg (F) and adult
		Kit Carson	McCampbell *(36*)*, egg (F) and adult
		Las Animas	McCampbell *(36*)*, egg (F) and adult
		Lincoln	McCampbell *(36*)*, egg (F) and adult
		Otero	McCampbell *(36*)*, egg (F) and adult
		Prowers	McCampbell *(36*)*, egg (F) and adult
	Kansas:	Grant	Wilbur *(61*)*
		Gray	Wilbur *(61*)*
		Greeley	Wilbur *(61*)*
		Hamilton	Wilbur *(61*)*
		Morton	Wilbur *(61*)*
		Stanton	Wilbur *(61*)*
		Stevens	Wilbur *(61*)*
		Wallace	Wilbur *(61*)*
	New Mexico:	Union	Hollinger *(24*)*
	Oklahoma:	Cimarron	Bieberdorf *(61*)*, egg (F) and adult Stiles et al. *(92)* nymph Fenton *(10*)*
		Texas	Bieberdorf *(61*)*, egg (F) and adult Stiles *(92)*

Year	State and county		Reference or collector
1937	Colorado:	Adams	McCampbell *(38*)*, egg (F)
		Baca	McCampbell *(38*)*, egg (F) and nymph; *(62*)*, adult
		Bent	McCampbell *(38*)*, egg (F) and nymph; *(62*)*, adult Morton *(63*)*
		Cheyenne	McCampbell *(62*)*, egg (F) and adult *(38*)*, nymph Morton *(63*)*
		Crowley	McCampbell *(38*)*, egg (F) and adult
		Custer	McCampbell *(38*)*, egg (F) and adult
		Denver	Morton *(63*)* Wallace *(17*)*
		Douglas	McCampbell *(38*)*
		Elbert	McCampbell *(38*)*, egg (F) and adult Willis *(63*)*
		El Paso	McCampbell *(38*)*, egg (F), nymph, and adult Willis *(63*)*
		Fremont	McCampbell *(38*)*, egg (F); *(62*)*, adult Willis *(63*)*
		Huerfano	McCampbell *(38*)*, egg (F) and adult Willis *(63*)*
		Kiowa	McCampbell *(38*)*, egg (F) and nymph; *(62*)*, adult Morton *(63*)*
		Kit Carson	McCampbell *(62*)*, egg (F) and adult; *(38*)*, nymph Morton *(63*)*
		Las Animas	McCampbell *(38*)*, egg (F), nymph, and adult Morton *(63*)*, nymph and adult

Year	State and county		Reference or collector
1937	Colorado:	Lincoln	McCampbell *(38*)*, egg (F), nymph, and adult
			Shotwell *(48*)*, nymph
			Morton *(48*)* nymph and adult
		Otero	McCampbell *(38*)*, egg (F) and nymph; *(62*)*, adult
			Willis *(63*)*
		Phillips	McCampbell *(38*)*
		Prowers	McCampbell *(38*)*, egg (F) and nymph; *(62*)*, adult
			Morton *(63*)*
		Pueblo	McCampbell *(38*)*, egg (F) and adult
			Willis *(63*)*
		Sedgwick	McCampbell *(62*)*
		Washington	McCampbell *(62*)*
		Weld	McCampbell *(62*)*
		Yuma	McCampbell *(38*)*
	Kansas:	Butler	Kelly and Portman *(62*)*
		Clark	Kelly and Portman *(62*)*
		Comanche	Kelly and Portman *(62*)*, egg (F)
		Ellis	Morton *(63*)*
		Finney	Kelly and Portman *(62*)*
		Ford	Portman *(63*)*
		Gove	Portman *(81*)*
		Gray	Kelly and Portman *(62*)*
		Greeley	Kelly and Portman *(62*)*
		Hamilton	Kelly and Portman *(62*)*
		Logan	Morton *(63*)*
		Meade	Kelly and Portman *(62*)*, egg (F) and adult
		Osborne	Portman *(63*)*
		Ottawa	Portman *(63*)*
		Pawnee	Kelly and Portman *(62*)*
		Riley	Moore *(63*)*
		Rush	Kelly and Portman *(62*)*

Year	State and county		Reference or collector
		Russell	Kelly and Portman *(62*)*
		Seward	*(81*)*
		Stanton	Kelly and Portman *(62*)*
		Thomas	Morton *(63*)*
		Wallace	Kelly and Portman *(62*)*
			Morton *(63*)*
	Nebraska:	Box Butte	Morton *(63*)*
		Deuel	Morton *(63*)*
		Grant	Morton *(63*)*
		Hitchcock	Morton *(63*)*
	New Mexico:	Colfax	Ginn *(62*)*, egg (F) and adult
		Curry	Ginn *(63*)* adult
			Boykin *(2*)*
		Harding	Ginn *(62*)*, egg (F) and adult
			Boykin *(2*)*
		Lea	Morton *(81*)*
		Mora	Ginn *(62*)*, egg (F) and adult
			Boykin *(2*)*
		Quay	Ginn *(62*)*, egg (F) and adult
			Boykin *(2*)*
		San Miguel	Boykin *(2*)*
		Union	Ginn *(62*)*, egg (F) and adult
			Boykin *(2*)*, nymph
	Oklahoma:	Alfalfa	Stiles et al. *(62*)*
		Beaver	Shotwell *(62*)*
		Beckham	Kaiser and Standish *(16*)*
		Blaine	Shotwell *(62*)*
		Canadian	Shotwell *(62*)*
		Cimarron	Stiles et al. *(62*)*, egg (F)
			Morton *(63*)*
			Hubbell *(17*)*
			Shotwell *(62*)*
		Custer	Kaiser *(16*)*
		Dewey	Shotwell *(62*)*
		Garfield	Stiles et al. *(62*)*
		Grant	Stiles et al. *(62*)*
		Greer	Stiles et al. *(62*)*
		Harmon	Stiles et al. *(62*)*, egg (F)
			Shotwell *(62*)*
			Blair *(17*)*

Year	State and county		Reference or collector
1937	Oklahoma:	Harper	Shotwell *(62*)*
		Jackson	Stiles et al. *(62*)*
		Kay	Hubbell *(17*)*
		Oklahoma	Stiles et al. *(62*)*
		Osage	Blair *(19*)*
		Payne	*(77*)*
		Pittsburg	*(77*)*
		Texas	Stiles et al. *(62*)*, egg (F) and adult
			Hubbell *(19*)*
		Woods	Stiles et al. *(62*)*
		Woodward	Shotwell *(62*)*
	South Dakota:	Beadle	Sanderson *(63*)*
		Todd	Sanderson *(63*)*
	Texas:	Carson	Reppert and Gable *(62*)*
			Morton *(63*)*
		Dallam	Reppert and Gable *(62*)*
			Morton *(63*)*
		Donley	Reppert and Gable *(62*)*, egg (F) and adult
		Hansford	Reppert and Gable *(62*)*
		Hartley	Reppert and Gable *(62*)*, egg (F) and adult
		Moore	Reppert and Gable *(62*)*, egg (F) and adult
			Morton *(63*)*
		Ochiltree	Reppert and Gable *(62*)*
1938	Colorado:	Adams	McCampbell *(40*)*, egg (F) and adult
			Robb *(64*)*, egg (F) and adult
		Arapahoe	McCampbell *(40*)*, egg (F)
			Robb *(64*)*
		Baca	McCampbell *(40*)*, egg (F), nymph, and adult
			Nuoci *(64*)*, egg (F)
			Hupper *(64*)*
		Bent	McCampbell *(40*)*, egg (F), nymph, and adult
			Beals *(64*)*, egg (F) and adult

Year	State and county	Reference or collector
	Cheyenne	McCampbell *(40*)*, egg (F), nymph, and adult
		Biederman *(64*)*, egg (F)
		Kropf *(64*)*
	Crowley	McCampbell *(40*)*, egg (F), nymph, and adult
		Kropf *(64*)*, egg (F) and adult
	Custer	McCampbell *(40*)*, nymph
	Elbert	McCampbell *(40*)*, egg (F), nymph, and adult
		Lewis *(64*)*, egg (F) and adult
		Morton *(65*)*, nymph
	El Paso	McCampbell *(40*)*, nymph
		Mickle *(65*)*
		Wallace *(17*)*
	Fremont	McCampbell *(40*)*, nymph
		Biederman *(65*)*
	Huerfano	McCampbell *(40*)*, nymph
		Giles *(64*)*
	Jefferson	McCampbell *(40*)*
	Kiowa	McCampbell *(40*)*, egg (F), nymph, and adult
		Nuoci *(64*)*, egg (F)
		Kropf *(64*)*
	Kit Carson	McCampbell *(40*)*, egg (F), nymph, and adult
		Biederman *(64*)*, egg (F) and adult
	Las Animas	McCampbell *(40*)*, egg (F), nymph, and adult
		Nuoci *(64*)*, egg (F) and adult
	Lincoln	McCampbell *(40*)*, egg (F), nymph, and adult
		Biederman *(64*)*, egg (F)
		Lewis *(64*)*

Year	State and county		Reference or collector
1938	Colorado:	Logan	Mickle *(65*)*
		Morgan	Mickle *(65*)*
		Otero	McCampbell *(40*)*, egg (S), nymph and adult
			Beals *(64*)*, egg (F) and adult
		Prowers	Nuoci *(64*)*, egg (F)
			Hupper *(64*)*
		Pueblo	McCampbell *(40*)*, nymph
			Mickle *(65*)*
		Washington	McCampbell *(40*)*, egg (F) and adult
			Biederman *(64*)*, egg (F)
			Mickle *(64*)*
	Kansas:	Butler	Curtiss *(64*)*
		Clark	Curtiss *(64*)*
		Brown	Portman *(65*)*
		Ellis	McDonald *(64*)*, egg (F) and adult
		Dickinson	McDonald *(65*)*
		Finney	Curtiss *(64*)*
		Ford	Curtiss *(64*)*
		Grant	Curtiss *(64*)*
		Greeley	McDonald *(65*)*
		Hamilton	Curtiss *(64*)*
		Hodgeman	Curtiss *(64*)*
		Kearny	Curtiss *(64*)*
		Lane	McDonald *(64*)*
		Meade	Hibbard *(17*)*, nymph
			Curtiss *(64*)*
			(17)*
		Morton	Curtiss *(64*)*
		Ness	McDonald *(64*)*
		Pawnee	McDonald *(64*)*
		Rush	McDonald *(64*)*
		Scott	McDonald *(64*)*
		Seward	Curtiss *(64*)*
		Stanton	Curtiss *(64*)*
		Stevens	Curtiss *(64*)*
		Thomas	Portman *(65*)*
		Wallace	McDonald *(64*)*
		Wichita	McDonald *(64*)*
	Nebraska:	Clay	Eckhoff *(65*)*
	New Mexico:	Colfax	Landrum *(7*)*, egg (F)
			Hildwein *(19*)*, egg (S) and nymph
			Resley *(64*)*

Year	State and county	Reference or collector
	Curry	Landrum *(64*)*, egg (F) Hare *(64*)*
	DeBaca	Landrum *(7*)*, egg (F) and adult
	Guadalupe	Landrum *(7*)*, egg (F) Resley *(64*)*
	Harding	Landrum *(7*)*, egg (F) Hildwein *(19*)*, egg (S) and nymph Resley *(64*)*
	Lea	Landrum *(64*)*
	Mora	Hildwein *(19*)*, egg (S) and nymph Landrum *(7*)*, egg (F) and adult
	Quay	Hildwein *(19*)*, egg (S) and nymph Landrum *(9*)*, egg (F) Landrum *(64*)*
	Roosevelt	Landrum *(64*)*
	San Miguel	Landrum *(64*)*, egg (F) Hare *(64*)*
	Union	Landrum *(7*)*, egg (F) Hildwein *(19*)*, egg (S) and nymph Resley and Hare *(64*)*
	Oklahoma: Alfalfa	Williams *(65*)*
	Beaver	Landrum *(7*)*, egg (F) Moore *(64*)*
	Beckham	Williams *(64*)* Moore *(64*)*, egg and adult
	Cimarron	Landrum *(7*)*, nymph Stiles *(75*)*
	Comanche	Williams *(65*)*
	Custer	Williams *(65*)*
	Ellis	Moore *(64*)*
	Garfield	Moore *(64*)*
	Grant	Williams *(64*)*
	Greer	Williams *(64*)*
	Harmon	Williams *(64*)*
	Harper	Moore *(64*)*
	Haskell	Williams *(64*)*
	Jackson	Williams *(64*)* Blair *(17*)*, nymph
	Kay	Williams *(65*)*
	Kingfisher	Williams *(64*)*
	Kiowa	Williams *(64*)*

Year	State and county		Reference or collector
1938	Oklahoma:	Le Flore	Williams *(64*)*
		McIntosh	Williams *(64*)*
		Major	Moore *(64*)*
		Okfuskee	Williams *(64*)*
		Oklahoma	Moore *(64*)*
		Okmulgee	Williams *(64*)*
		Payne	*(77*)*
			Williams *(65*)*
		Pittsburgh	*(77*)*
			Duck *(17*)*
		Roger Mills	Moore *(64*)*
		Sequoyah	Williams *(64*)*
		Texas	Moore *(64*)*, egg (F) and adult
		Tillman	Williams *(64*)*
		Washita	Williams *(64*)*
		Woods	Moore *(64*)*, egg (F) and adult
		Woodward	Moore *(64*)*
	Texas:	Armstrong	Clearman *(64*)*, egg (F) and adult
		Bailey	Clearman *(64*)*
		Briscoe	Clearman *(64*)*, egg (F) and adult
		Carson	Miller *(64*)*, egg (F)
			Clearman *(64*)*
		Castro	Clearman *(64*)*, egg (F) and adult
		Childress	Clearman *(64*)*
			Blair *(17*)*
		Cochran	Clearman *(64*)*
		Collingsworth	Clearman *(64*)*
		Crosby	Clearman *(64*)*
		Dallam	Landrum *(64*)*, egg (F)
			Miller *(64*)*, nymph and adult
		Dallas	Miller *(64*)*
		Deaf Smith	Clearman *(64*)*, egg (F) and adult
		Dickens	Williams *(64*)*, egg (F) and adult
		Floyd	Williams *(64*)*, egg (F)
			Clearman *(64*)*
		Foard	Miller *(64*)*
		Gray	Clearman *(64*)*, egg (F) and adult
		Hale	Williams *(64*)*, egg (F)
			Clearman *(64*)*

Year	State and county	Reference or collector
	Hall	Clearman *(64*)*, egg (F) and adult
	Hansford	Miller *(64*)*, egg and adult Landrum *(32*)*, nymph
	Hartley	Miller *(64*)*, egg (F) and adult Landrum *(32*)*, nymph
	Haskell	Miller *(64*)*
	Hemphill	Miller *(64*)*, egg (F) and adult Landrum *(32*)*, nymph
	Hockley	Clearman *(64*)*
	Howard	Williams *(64*)*, egg (F) and adult
	Hutchinson	Miller *(64*)*, egg (F) and adult
	King	Moore *(64*)*, egg (F) Miller *(64*)*
	Knox	Miller *(64*)*
	Lamb	Clearman *(64*)*, egg (F) and adult
	Lipscomb	Miller *(64*)*, egg (F) and adult
	Moore	Miller *(64*)*, egg (F) and adult Landrum *(32*)*, nymph
	Ochiltree	Miller *(64*)*, egg (F), nymph, and adult
	Oldham	Clearman *(64*)*, egg (F) and adult
	Parmer	Clearman *(64*)*, egg (F) and adult
	Potter	Miller *(64*)*, egg (F) and adult Landrum *(32*)*, nymph
	Randall	Clearman *(64*)*, egg (F) and adult
	Roberts	Miller *(64*)*, egg (F) Clearman *(64*)*
	Sherman	Miller *(64*)*, egg (F), nymph and adult
	Stonewall	Miller *(64*)*
	Swisher	Clearman *(64*)*, egg (F) and adult
	Terry	Williams *(64*)*, egg (F) and adult
Wyoming:	Campbell	Thrailkill *(5*)*

Year	State and county		Reference or collector
1939	Colorado:	Adams	Davis and Mickle *(7*)*, egg (S, F), nymph, and adult McCampbell *(41*)*, nymph and adult Shotwell *(68*)*, egg (F) Scharff *(6*)*, egg (S) Scharff *(57*)*
		Baca	Davis and Mickle *(7*)*, egg (S) and nymph McCampbell *(41*)*, nymph and adult Shotwell *(68*)*, egg (F) Hupper *(7*)* Scharff *(6*)*, egg (S) and nymph
		Bent	McCampbell *(41*)*, egg (F) and adult Davis and Mickle *(7*)*, egg (S) and nymph Hupper *(7*)* Shotwell *(68*)*, egg (F)
		Cheyenne	Davis and Mickle *(7*)*, egg (S, F), nymph, and adult Mickle *(7*)*, nymph McCampbell *(41*)*, nymph and adult Shotwell *(68*)*, egg (F) Scharff *(6*)*, egg (S) and nymph Scharff and Gardner *(7*)*, egg (F) and adult Scharff *(57*)*
		Crowley	Davis and Mickle *(7*)*, egg (S) and nymph Scharff *(6*)*, egg (S) and nymph McCampbell *(41*)*, nymph and adult Scharff *(57*)*
		Denver	Wakeland *(7*)*
		Douglas	Biederman *(7*)*
		Elbert	Davis and Mickle *(7*)*, egg (S) and nymph McCampbell *(41*)*
		El Paso	Biederman *(7*)*, egg (F) and adult

Year	State and county	Reference or collector
	Kiowa	Davis and Mickle *(7*)*, egg (S) and nymph Scharff *(6*)*, egg (S); *(57*)*, nymph Biederman *(7*)*, egg (F) and adult McCampbell *(41*)*
	Kit Carson	Davis and Mickle *(7*)*, egg (S) and nymph Biederman *(7*)*, egg and adult McCampbell *(41*)*
	Las Animas	Davis and Mickle *(7*)*, egg (S, F), nymph, and adult Shotwell *(57*)*, egg (F) Scharff and Wood *(7*)*, egg (F) Scharff *(6*)*, nymph; *(57*)*, adult Hupper *(7*)*
	Lincoln	Davis and Mickle *(7*)*, egg (S, F), nymph and adult Shotwell *(68*)*, egg (F) Scharff and Gardner *(7*)*, egg (F) Scharff *(7*)*, egg (S); *(6*)*, nymph; *(57)*, adult McCampbell *(41*)* Biederman *(7*)*
	Logan	Robb *(7*)*
	Morgan	Mickle *(7*)*
	Otero	Davis and Mickle *(7*)*, egg (S, F), nymph, and adult Scharff *(6*)*, egg (S) and nymph; *(57*)*, adult Shotwell *(68*)*, egg (F) Hupper *(7*)*, egg (F) and adult
	Phillips	Robb *(7*)*
	Prowers	Hupper *(7*)*
	Pueblo	Davis and Mickle *(7*)*, egg (F) and adult Shotwell *(68*)*, egg (F)

Year	State and county		Reference or collector
1939	Colorado:	Pueblo	Scharff and Gardner *(7*)*, egg (F) and adult
			McCampbell *(41*)*, nymph
			Scharff *(57*)*
		Sedgwick	Robb *(7*)*
		Washington	Davis and Mickle *(7*)*, egg (S) and nymph
			McCampbell *(41*)*
			Robb *(7*)*
		Weld	Gardner *(7*)*
		Yuma	Robb *(7*)*
			Wallace *(17*)*
	Kansas:	Barton	Tuck *(7*)*
		Decatur	Tuck *(7*)*
		Ellis	McDonald *(7*)*
		Finney	Spain *(67*)*
		Ford	Tuck *(7*)*
		Gove	McDonald *(7*)*
		Graham	Tuck *(7*)*
		Grant	Landrum *(7*)*, nymph
			Scharff *(6*)*, nymph
			Tuck *(7*)*
		Gray	Tuck *(7*)*
		Greeley	Landrum *(7*)*, nymph
			McDonald *(7*)*
		Hamilton	Landrum *(7*)*, nymph
		Haskell	Landrum *(7*)*, nymph
			McDonald *(7*)*
		Hodgeman	Tuck *(7*)*
		Jewell	McDonald *(7*)*
		Kearny	Scharff *(6*)*, nymph
			Tuck *(7*)*
		Kiowa	McDonald *(7*)*
		Logan	Tuck *(7*)*
		Meade	Tuck *(7*)*
		Mitchell	Kelly *(28*)*
			Tuck *(7*)*
		Morton	Landrum *(7*)*, nymph
			McDonald *(7*)*
		Ness	Tuck *(7*)*
		Norton	McDonald *(67*)*
		Osborne	Tuck *(7*)*
		Phillips	Tuck *(7*)*
		Pratt	Tuck *(7*)*
		Rawlins	Tuck *(7*)*
		Rooks	McDonald *(7*)*
		Rush	McDonald *(7*)*
		Russell	Tuck *(7*)*
		Scott	Tuck *(7*)*

Year	State and county		Reference or collector
		Seward	Landrum *(7*)*
			McDonald *(7*)*
		Sheridan	McDonald *(7*)*
		Sherman	McDonald *(67*)*
		Smith	Tuck *(7*)*
		Stafford	Tuck *(7*)*
		Stanton	Landrum *(7*)*, nymph
			Scharff *(6*)*, nymph
			Tuck *(7*)*
			Spain *(67*)*
		Stevens	Scharff *(6*)*, egg (S) and nymph
			Landrum *(7*)*, nymph
			Kelly *(28*)*, nymph
			Tuck *(7*)*
		Thomas	Tuck *(7*)*
		Wallace	McDonald *(7*)*
		Wichita	Tuck *(7*)*
	Nebraska:	Chase	Hauke *(7*)*
		Cherry	Eckhoff *(18*)*
		Dawson	Hauke *(7*)*
		Dundy	Hauke *(7*)*
		Frontier	Hauke *(7*)*
		Furnas	Hauke *(7*)*
		Hitchcock	Hauke *(7*)*
		Keith	Hauke *(7*)*
		Lancaster	Gates *(18*)*
		Perkins	Hauke *(7*)*
		Red Willow	Hauke *(7*)*
			Eckhoff *(18*)*
		Scotts Bluff	Eckhoff *(67*)*
	New Mexico:	Chaves	Shotwell *(68*)*, egg (F)
			Resley *(7*)*, egg (F) and adult
		Curry	Hildwein *(20*)*, egg (S) and nymph
			Ohls *(7*)*
		De Baca	Keys *(7*)*, egg (F)
			Landrum *(7*)*, egg (F)
			Shotwell *(68*)*, egg (F)
			Landrum and Spain *(7*)*, egg (F)
			Resley *(7*)*, nymph
			Ohls *(7*)*
		Guadalupe	Spain *(71*)*, egg (S) and nymph
			Resley *(7*)*, egg (S) and nymph
			Ohls *(7*)*
		Harding	Hildwein *(20*)*, egg (S) and nymph

Year	State and county	Reference or collector
1939	New Mexico: Harding	Resley *(7*)*, nymph
		Keys *(7*)*, egg (F) and adult
	Lea	Resley *(7*)*
	Quay	Spain *(71*)*, egg (S) and nymph
		Ohls *(7*)*, egg (F) and adult
		Shotwell *(68*)*, egg (F)
		Spain and Landrum *(7*)*, egg (F)
		Resley *(7*)*, nymph
		Furry *(17*)*
	Roosevelt	Resley *(7*)*
	San Miguel	Resley *(7*)*, nymph
		Ohls *(7*)*
	Union	Spain *(71*)*, egg (S) and nymph
		Resley *(7*)*, nymph and adult
		Keys *(7*)*
	Oklahoma: Alfalfa	Moore *(67*)*
	Beaver	Landrum *(7*)*, nymph
		Williams *(7*)*
	Caddo	Moore *(67*)*
	Cimarron	Stiles *(76*)*, egg and adult
		Miller *(7*)*, nymph and adult
		Spain *(67*)*
	Dewey	Moore *(67*)*
	Grant	Moore *(67*)*
	Harmon	Moore *(67*)*
	Harper	Moore *(67*)*
	Jefferson	Moore *(67*)*
	Kiowa	Moore *(67*)*
	Le Flore	Moore *(67*)*
	Texas	Miller *(7*)*, egg (S), nymph, and adult
		Spain *(67*)*
	Woods	Moore *(67*)*
	Woodward	Moore *(67*)*
	Texas: Armstrong	Spicer *(7*)*, egg (S) and nymph
		Williams *(7*)*
		Isely *(16*)*
	Bailey	Clearman *(7*)*
	Brewster	Isely *(16*)*
	Briscoe	Spain *(71*)*, egg (S) and nymph
		Clearman *(7*)*

Year	State and county	Reference or collector
	Carson	Spicer *(7*)*, egg (S) and nymph
		Williams *(7*)*
	Castro	Clearman *(7*)*, egg (S) and nymph
		Clearman *(6*)*
	Collingsworth	Williams *(7*)*
	Dallam	Ohls *(7*)*, egg (S)
		Spicer *(67*)*, nymph; *(6*)*, adult
	Deaf Smith	Clearman *(7*)*, egg (S) and nymph; *(6*)*, adult
		Spain *(67*)*
	Donley	Williams *(6*)*
	Floyd	Clearman *(7*)*, egg (S) and nymph; *(6*)*, egg (F) and adult
	Gaines	Clearman *(6*)*
	Gray	Spicer *(7*)*, egg (S) and nymph
		Williams *(6*)*
		Spain *(67*)*
	Hale	Clearman *(7*)*, egg (S) and nymph; *(6*)*, adult
	Hansford	Spicer *(7*)*, egg (S) and nymph; *(6*)*, adult
	Hartley	Spain *(71*)*, egg (S) and nymph
		Spicer *(67*)*, nymph; *(6*)*, adult
	Hemphill	Williams *(6*)*
	Hutchinson	Spain *(71*)*, egg (S); *(6*)*, nymph
		Spicer *(67*)*, nymph; *(6*)*, adult
	Lamb	Clearman *(7*)*, egg (S) and nymph; *(6*)*, adult
	Lipscomb	Williams *(6*)*, nymph and adult
	Moore	Spain *(71*)*, egg (S) and nymph
		Spicer *(67*)*, nymph; *(6*)*, adult
	Ochiltree	Spicer *(67*)*, nymph
		Williams *(6*)*
	Oldham	Spain *(71*)*, egg (S) and nymph

Year	State and county		Reference or collector
1939	Texas:	Oldham	Spicer *(67*)*, nymph; *(6*)*, adult
		Parmer	Clearman *(7*)*, egg (S) and nymph; *(6*)*, adult
		Potter	Spain *(71*)*, egg (S) and nymph
			Spicer *(67*)*, nymph; *(6*)*, adult
		Randall	Spain *(71*)*, egg (S) and nymph
			Clearman *(6*)*
		Roberts	Williams *(6*)*
		Sherman	Ohls *(7*)*, egg (S) and nymph
			Spicer *(7*)*, nymph; *(6*)*, adult
			Spain *(67*)*
		Swisher	Spain *(71*)*, egg (S) and nymph
			Clearman *(6*)*
		Wheeler	Williams *(6*)*
		Yoakum	Landrum *(7*)*, nymph
			Clearman *(6*)*
	Wyoming:	Goshen	Beals *(6*)*
			Skoog *(81*)*
1940	Colorado:	Adams	Mickle *(83*)*, egg (S) and nymph
		Cheyenne	Mickle *(83*)*, egg (S)
		Crowley	Mickle *(83*)*, nymph
		El Paso	Mickle *(83*)*, egg (S) and nymph
		Las Animas	Mickle *(83*)*, egg (S) and nymph
			Scharff *(57*)*, egg (S)
		Lincoln	Mickle *(83*)*, egg (S) and nymph
			Scharff *(69*)*
		Morgan	Scharff *(69*)*
		Otero	Mickle *(83*)*, egg (S) and nymph
			Scharff *(57*)*, egg (S)
		Prowers	Scharff *(69*)*
		Pueblo	Mickle *(83*)*, egg (S) and nymph
		Yuma	Scharff *(69*)*
	Kansas:	Lincoln	Tuck *(69*)*
		Ness	Tuck *(69*)*
		Phillips	Tuck *(69*)*
	New Mexico:	Chaves	Landrum *(83*)*, egg (S) and nymph

Year	State and county		Reference or collector
		De Baca	Landrum *(83*)*, egg (S) and nymph
			Scharff *(57*)*, egg (S)
		Eddy	Scharff *(57*)*, nymph and adult
		Quay	Landrum *(83*)*, egg (S) and nymph
			Scharff *(57*)*, egg (S)
	Texas:	Presidio	Tinkham *(96)*
	Wyoming:	Platte	Morton *(81*)*
1941	Colorado:	Cheyenne	Scharff *(84*)*, nymph
		Crowley	Scharff *(84*)*, nymph
		Kiowa	Scharff *(84*)*, nymph
		Lincoln	Scharff *(84*)*, nymph
			Skoog *(81*)*
		Otero	Skoog and Willis *(81*)*
		Prowers	Scharff *(84*)*, nymph
		Pueblo	Scharff *(84*)*, nymph
	Kansas:	Haskell	Scharff *(84*)*, nymph
		Kearny	Scharff *(84*)*, nymph
		Saline	Shotwell *(81*)*
		Seward	Scharff *(84*)*, nymph
	New Mexico:	Lea	Scharff *(84*)*, nymph
	South Dakota:	Shannon (Washington)	Weyl *(87*)*
1942	Nebraska:	Banner	Newton *(81*)*
	South Dakota:	Washington	Skoog *(81*)*
1948	Colorado:	Baca	Bakke *(85*)*
		Cheyenne	Landrum and Spicer *(85*)*
		Crowley	Kropf *(43*)*
		El Paso	Parker *(85*)*
		Las Animas	Stewart *(85*)*
1950	Texas:	Potter	Spicer *(86*)*
1951	Kansas:	Hamilton	Ridgway *(23*)*
	New Mexico:	Union	Landrum *(23*)*
1952	New Mexico:	Union	Spicer *(8*)*
			Bergstrom *(8*)*
1955	New Mexico:	Union	Hauke *(8a*)*
1956	New Mexico:	Union	Hauke *(8b*)*
1957	New Mexico:	Union	Seaton *(8c*)*

Incomplete Records

Colorado:	Bent	Snow *(16*)*
	Larimer	Caudell *(26)*
	Logan	*(16*)*
	Otero	Skinner *(17*)*

Year	State and county	Reference or collector
	Iowa:	
	Des Moines	Jackman *(57)*
	Kansas	
	Barber	Cragin *(16*)*
		(41)
		(7)
	Butler	*(41)*
	Cheyenne	*(41)*
		Williams *(16*)*
		(7)
	Comanche	*(7)*
	Decatur	*(41)*
		Williams *(16*)*
		(7)
	Ford	*(41)*
		(7)
	Grant	*(41)*
		(7)
	Greeley	*(41)*
		Williams *(16*)*
		(7)
	Hamilton	*(41)*
		(16)*
	Harper	*(41)*
		(7)
	Hodgeman	*(41)*
	Logan	*(41)*
		Snow *(16*)*
		(7)
	Meade	*(41)*
		(7)
	Morton	*(41)*
		(7)
	Ness	*(41)*
	Norton	*(41)*
	Osborne	*(41)*
	Pratt	*(41)*
		(7)
	Scott	*(41)*
		(7)
	Sedgwick	*(41)*
	Sheridan	*(41)*
	Sherman	*(41)*
		(7)
	Stanton	*(41)*
		(7)
	Stevens	*(7)*
	Trego	*(41)*
	Wichita	*(41)*
		Williams *(16*)*
		(7)
	Wilson	*(41)*

Year	State and county		Reference or collector
	Nebraska:	Box Butte	Hebard *(18*)*
		Cheyenne	*(16*)*
		Lancaster	Hebard *(16*)*
		Sioux	Hebard *(18*)*
	New Mexico:	Chaves	Smith *(15*)*
	Oklahoma:	Beckham	*(41)*
		Custer	Hebard *(42)*
	Texas	Dallas	Boll *(17*)*
			Riley *(15*)*
	Wyoming:	Albany	Pfadt *(50*)*

HABITAT

During the 90 years the High Plains grasshopper has been known, it has not extended its habitat beyond a comparatively small region, although it has many times migrated great distances. It may logically be concluded that limitations to expansion of its habitat will be operative in the future as they have been in the past, and that the habitat will remain about where it is. The species has been of little economic importance in counties on the perimeter of its habitat.

Geographically, the habitat, as shown in figure 5, is limited to an area in about the center of the High Plains. This area is about 200 miles wide by 350 miles long in the widest and longest places, but the area does not exceed about 50,000 square miles. Ecological, climatic, and topographical conditions limit the habitat of the insect to a relatively small area in southeastern Colorado, southwestern Kansas, the Oklahoma Panhandle, the Texas Panhandle, and northern New Mexico, all within the short-grass area of the plains.

The habitat is confined ecologically to the short-grass belt, principally to the grama grass association. It is confined topographically to an elevation of from 3,000 to 6,000 feet, mainly from 4,000 to 6,000 feet. It is confined climatically, east and west, to the 15-inch or less annual rainfall belt, and north and south to a zone where the average winter temperature is from approximately 28° to 38° F.

The High Plains were studied, described, mapped, and named by Willard D. Johnson *(50)* of the United States Geological Survey. He considered them as a topographical unit and described them as follows (*pp. 610-611, 658-659*):

> The High Plains approximately correspond to what is sometimes called, merely for convenience of subdivision, the Central Plains region. They lie in irregular belt form about midway across the long eastward slope of the Great Plains. They have fairly definite boundaries, however, and are in fact a natural subdivision of the Great Plains area.
>
> The Great Plains as a whole constitute a geographic unit. Their extent is so great that they are properly to be regarded as one of the primary divisions of the continent. In that broad sense they are a plain. But topographically they present, in the main, an erosion

surface—a surface of degradation—with topographic diversity. That is, in detail they have not, in the main, the character of a plain.

The High Plains are the exception. They have practically no drainage, the local precipitation being disposed of by absorption. Comparatively, therefore, their surface has the general effect of a dead level. Indeed, by way of distinction, they are to some extent locally known as "The Flats" . . . Of the Great Plains area they are a natural subdivision by topographic difference. In this sense they are a topographic unit.

At the same time they are upland or plateau flats. And they are upland flats of survival; differential erosion of an original vastly extended plane surface has left here a fragment, or a close assemblage of fragments, in relief. The relief is not considerable. It is, however, sufficient to be dominating. But the High Plains—locally so called to some extent also—are individual more because of the conspicuous contrast of surface character they present. They are virtually unscored by erosion; though but a fractional part of the whole slope, they are yet absolutely of great size, and the traveler upon them immediately recognizes that they constitute the Plains proper. . . .

[*A Climatical Unit.*—] The Great Plains area, furthermore, may be regarded as naturally subdivided into belts by climatic difference also. In its westward rise of thousands of feet it passes through climatic gradations from humid to arid. Although, necessarily, along a uniformly rising slope, the passage is gradual, so that any subdivision must be arbitrary, it may at least be said that midway, across a considerable breadth, the climate is semiarid or subhumid. Indeed, the vague Central Plains region is sometimes called the Subhumid Belt. Agreeing generally in position with the topographic subdivision of the High Plains is this subdivision by climatic difference. The boundaries of the topographic belt, to a considerable extent, have been given sharp definition by marginal recession—a work of headstream sapping and encroachment from the eroded area . . . —and the topographic belt in consequence lies somewhat contracted within the limits of the climatic belt; but substantially there is agreement in position. Cause and effect here may appear to be far apart, but it is not difficult to trace their connection. . . .

[*Factors Which Make Up Climate.*—] The factors which, from the point of view of the farmer, go to make up climate are not only precipitation and its distribution throughout the year. The barren Staked Plains of Texas have a precipitation fully equal to that of the major portion of the wheat lands of the Dakotas, and it is of the same type of monthly distribution; but they are in effect much drier, since other conditions, conducive to greater evaporation, notably reduce the soil moisture available for growing crops. These other conditions are: (1) A more spasmodic character of the summer rains, favoring evaporation as against soil absorption; (2) a higher temperature resulting in a lower "relative humidity" . . . ; (3) more hours of sunshine; and (4) a greater wind movement.

The meteorological records of the United States Weather Bureau offer abundant data for a statement, sufficiently definite for present purposes, of the climate of the High Plains, expressed in terms of normal precipitation, temperature, relative humidity, sunshine and cloudiness, wind movement, and evaporation, both averaged for the year and, what is of much more practical interest, presented for the crop-growing season only. At the same time they show that the changes of climate, which on several occasions have extended the humid area nearly to the foothills of the mountains, and again have contracted it, to the serious injury of established farming interests to the eastward, are but oscillations across a stable mean and have fairly definite periods.

* * * * * * * * * * * *

[*Precipitation Belts of the Great Plains.*—] These records . . . show uniform decline in precipitation across the Great Plains westward, with rise again to comparative humidity locally in the Rocky

Mountains. Upon a climatic map this gradation in precipitation might be represented by north-south belts, indicating four subdivisions westward, as humid, subhumid, arid, and, again, subhumid. The High Plains would be seen to be included within the second or subhumid division. As a topographic zone of virtually no erosion this region of flat uplands would show fading off on the west into the eroded country of the arid belt, but abrupt termination on the east along a much-indented escarpment, well within the subhumid limits. The remaining strip would represent a zone of sharp erosion—a zone of capture by headwater sapping on the part of the multitude of streams of the humid belt. . . . the High Plains [are] a broad terrace of survival within the belt of medium precipitation.

But a map which should show precipitation only would not be complete as a climatic map. To the northward upon the Great Plains it would not be even approximately accurate. For example, precipitation on the Staked Plains as represented by the . . . record at the Amarillo station in the center of the Panhandle of Texas, is 21.94 [20.99][3] inches; at Garden [City], midway across the High Plains, in central-western Kansas, it is 17.38 [19.01] inches; at Goodland, northwestern Kansas, at about the northern limit of the High Plains, it is approximately 21 [17.67] inches; while in central North Dakota it is but 18 inches, and at St. Vincent, near the northeastern corner of that State . . . it is only 19.5 inches. In short, the vast barren flats of the High Plains have a slightly greater precipitation than even the major portion of the wheat lands of the Northwest. . . .

Nearly all of the High Plains is in the plains grassland known as the short-grass area or belt. It was discussed and described by Shantz *(78)* in 1923. He said *(pp. 89-90, 92-93, 105):*

The typical appearance of this grassland as a whole is that of a closely pastured meadow. Except during years of more than normal rainfall the taller growing plants are almost entirely absent, and the vegetation presents the appearance of extreme monotony. There is little variation in appearance from north to south or east to west. Changes in the vegetation within the area are due largely to differences in soil texture, run-off or flood-water irrigation which affect the available soil moisture supply.

* * * * * * * * * * * *

The short-grass formation is typical for the Great Plains. Along the Canadian boundary it occurs from western North Dakota across Montana to the Rocky Mountains. It extends in a broad band down across the Great Plains and almost to the southern escarpment of the High Plains in Texas. . . . [The western boundary follows the east side of the Rocky Mountains to the Montana-Wyoming boundary where it turns east to the eastern side of the Big Horn Mountains, extending south to the lower end of the Sangre de Christo range.] The [eastern] boundary [from Brule County, S. Dak.] then swings west around the great sand-hill area of Nebraska, then southeast and south across Kansas a little west of the 99th degree of west longitude, bending westward and extending south along the east boundary of the "Panhandle" of Texas. In Texas the short-grass formation is limited to the "Panhandle" and the southern portion of the High Plains. In eastern New Mexico it is also limited to the High Plains and to portions of northeastern New Mexico. . . .

Grama-grass Association . . .—The dominant plant in this association is grama grass *(Bouteloua gracilis)*. . . . In general appearance it is typical short-grass land.

The area occupied by this association forms a wedge, very broad in the north and very narrow in the south, lying just east of the

[3] Figures in brackets show latest established normals.

mountains. In Montana it extends from the mountains on the west to the eastern boundary of the state, but in Colorado forms only a narrow band.

This grassland occupies a soil which is very shallow, ranging in depth from 8 to 18 inches to the layer of carbonate accumulation, below which is a permanently dry subsoil. . . . There is no storage of water from year to year, and only during years of exceptional rainfall does water penetrate the soil below the layer of carbonate accumulation. . . .

Grama and buffalo-grass association . . .—The grama and buffalo-grass association is typical of the High Plains. The plant cover is often uniform and covers the ground with an open or dense mat-like growth. During wet years the short grass flowers and many annuals and perennials become prominent in the plant cover. It is dominated by almost equal quantities of grama grass *(Bouteloua gracilis)* and buffalo grass *(Bulbilis dactyloides)*. Often the cover is almost pure but at other times there are mixed with these grasses many small annuals . . . During years of more than normal rainfall, other and more prominent plants . . . are prominent.

This association extends from South Dakota across western Nebraska, eastern Colorado, southwestern Kansas, northeastern New Mexico, western Oklahoma, and northwestern Texas.

. . . The soil is not as shallow as under grama grass, the depth to the layer of carbonate accumulation ranging from 14 to 18 inches. . . .

Black grama association . . .—Black grama *(Bouteloua eriopoda)* characterizes the dry desert plains of west Texas and New Mexico. It does not form a sod but rather an open grass cover. Black grama is seldom an unmixed grassland, and there are often yucca, mesquite, and other desert shrubs scattered over the grass cover. The soil is shallow, often with carbonates at the surface. Rainfall usually starts growth during the summer when the temperature is high and evaporation rapid. . . .

Speaking of the short-grass plains, Weaver and Clements *(108, pp. 402-403)* say:

The grasses form a low mat or sod due to extensive propagation by rhizomes and stolons. In the drier portions, much soil surface is exposed, but under more favorable moisture conditions, the sod mats are more nearly continuous. Because of deficiency of soil moisture and severe summer drought, the vegetation matures early . . . The grasses "cure" on the ground but may resume growth upon the advent of opportune showers. Precipitation is so limited that the soil is seldom moist below a depth of 2 feet. Water penetrates slowly, owing in part to the high water-retaining power of the surface layers of fine sandy-loam or clay-loam soils and also to the vigorous absorption by the short grasses. The small amount of moisture, if any, stored during the winter season in the foot or two of surface soil, together with the rainfall of spring and early summer, may enable growth to continue until early July, when usually all the soil moisture is exhausted. As a consequence, deeply rooted tall grasses and other herbs are frequently excluded, and the typical short-grass cover is very uniform and monotonous as a result.

During unusually dry years even short grasses may fail to flower, but during wet ones growth may continue without interruption. The continued penetration of water to only 16 to 24 inches has resulted in a concentration of the leached salts and alluviated clay, which form a carbonate layer varying from 8 to 24 inches in thickness and sometimes occurring at depths of only 8 to 10 inches. Below the hardpan occurs a dry subsoil. By hindering water penetration . . . the native vegetation has exerted a profound effect upon soil structure and soil profile in the short-grass plains.

Comparison of the area in which grama grass is dominant or sub-dominant with a soils map of the Great Plains suggests that

the cause of short grass being restricted eastward and westward is the soil on which it grows. (See fig. 7.) The short-grass area

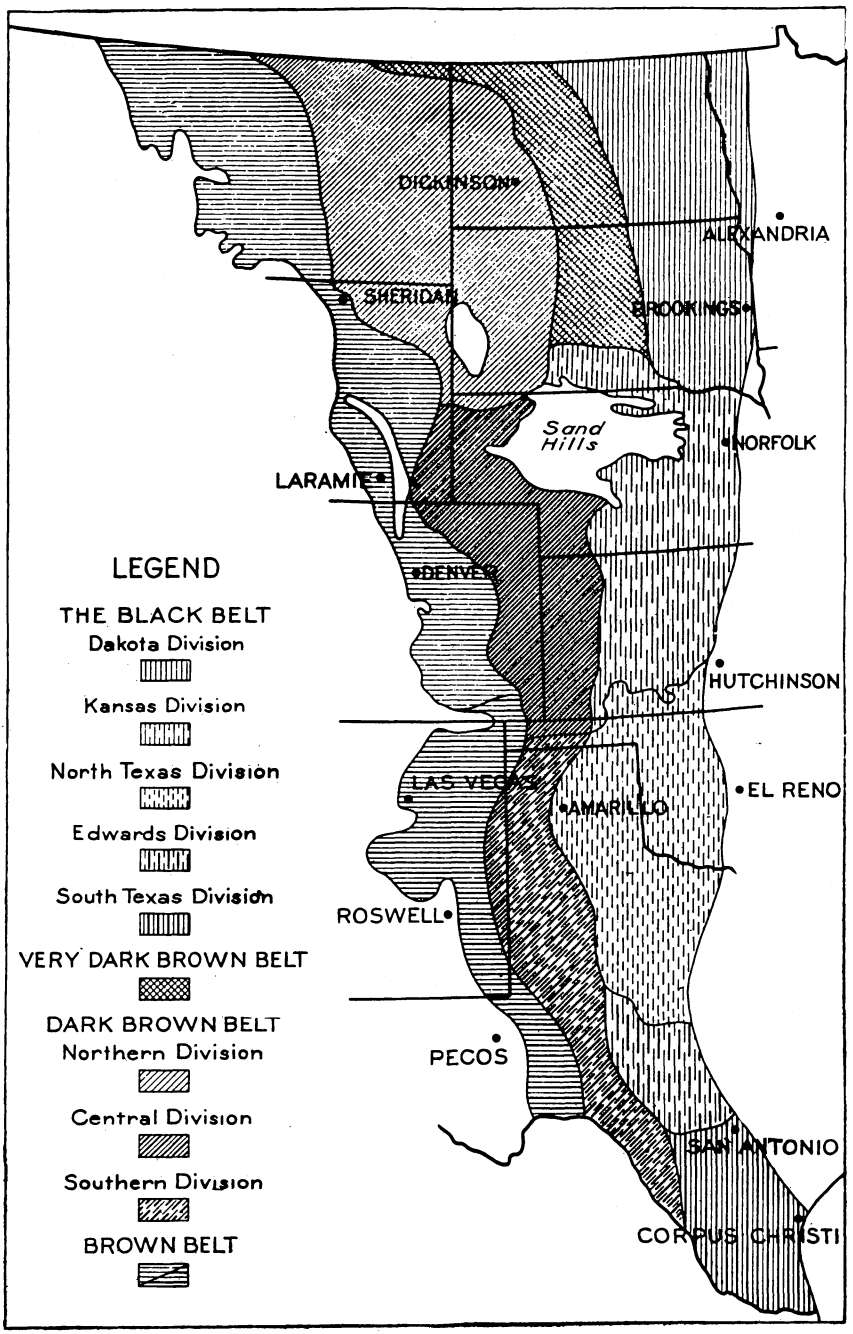


FIGURE 7.—Soil map of the Great Plains. [From drawing by C. F. Marbut, *(60)*.]

mainly coincides with what Marbut *(60)* calls the dark brown and the brown soil belts. He describes the general features, boundaries, and profiles of the soil as follows *(pp. 42-43, 62)*:

> The Great Plains . . . include that part of the United States, lying east of the Rocky Mountains, in which the soils are characterized, at maturity of development by (1) the presence, on some horizon of the soil section or profile, of a zone of alkaline salt accumulation, usually, not exclusively, lime carbonate and (2) a relatively dark colored surface soil. The color varies, from place to place, in degree of darkness but throughout the region it is darker than the mature soil in any other part of the country in which the zone of salt accumulation is present in the soil.
>
> * * * * * * * * * * * *
>
> *The Eastern Boundary.*—Since a dark surface soil is characteristic not only of the soils of the Great Plains, but of an extensive region east of the Great Plains, it is evident that the eastern boundary of the region must be determined on the basis of the other characteristic of the Great Plains soils—the zone of carbonate accumulation. Since the Great Plains region as defined, does not extend east of the area in which the zone of carbonate accumulation is present it is evident that the eastern boundary is also the boundary of the zone of carbonate accumulation.
>
> Since nature rarely establishes sharp boundaries, and since man must usually do so, we define the eastern boundary of the Great Plains as the line along which the zone of carbonate accumulation, universally present throughout the Great Plains, disappears entirely or becomes so faintly developed that it cannot be identified by ordinary field observation. . . .
>
> * * * * * * * * * * * *
>
> *The Western Boundary.*— . . . the Rocky Mountains bound the Great Plains on the west. This is in general true, but, . . . they seem to be more or less accidentally situated along the western boundary since this line would be, in part at least, where it is if the mountains did not exist. The western boundary where the mountains do not fix it, must be established on the basis of soil color, since the other soil characteristic of the Great Plains, the presence of a zone of carbonate accumulation, extends westward far beyond their western boundary. The western boundary therefore lies along that line or zone which divides the dark colored soils of the Great Plains from the light colored soils of the region west of the Great Plains, leaving the mountains out of consideration.
>
> [A soil profile in the dark-brown belt near Two Buttes, Colo., is as follows:]

	Inches
1. Brown clay loam, dark shade, somewhat granular	0 to 8
2. Brown clay loam, cloddy	8 to 11
3. Calcareous horizon	11+

The habitat of the High Plains grasshopper is all within the High Plains and nearly altogether within the grama grass association area. This is clearly shown in figure 8, which is an adaptation from Johnson's map of the High Plains *(50)* and Shantz' sketch map of the Great Plains region *(79)* showing the areas occupied by the principal plant communities. The only area where one of the species of grama grasses is not dominant and where *longipennis* is known to have reproduced is a small portion of the wire grass area in southwestern Kansas, northwestern Oklahoma, and in the eastern part of the Texas Panhandle. In this wire grass

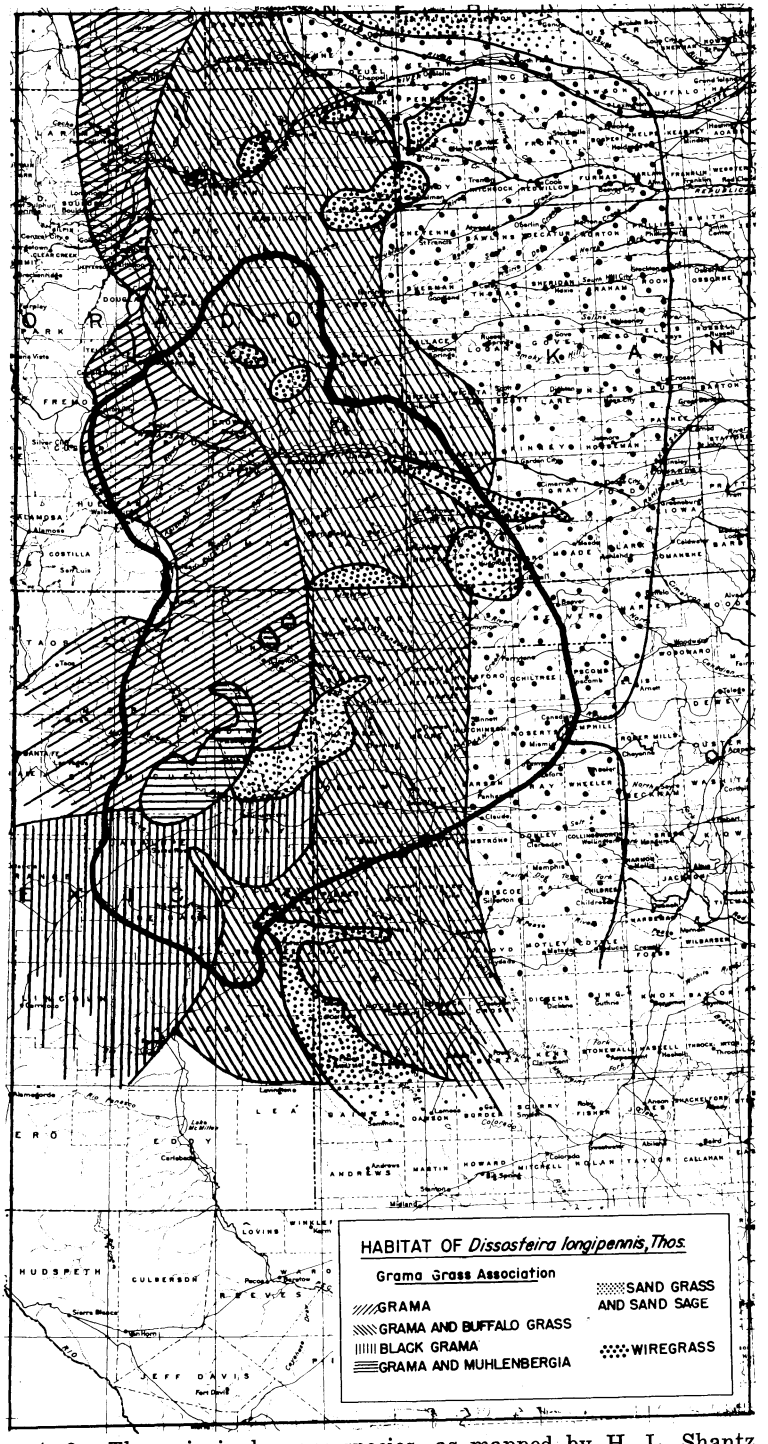


FIGURE 8.—The principal grass species, as mapped by H. L. Shantz *(78)*. Habitat of *longipennis* outlined by heavy line.

area it has not long survived and has been of little or no economic importance.

Although research has not been conducted that provides proof that *longipennis* breeds only in areas where grama grass is dominant or sub-dominant, voluminous observations by collectors, insect surveyors, and control men support that conclusion. Granting this, the fact throws no light upon why the habitat does not extend farther northward or southward while the grama grass association extends into Canada and almost into Mexico.

The habitat lies altogether within the elevation belt of 3,000 to 6,000 feet, and the most troublesome, persistent infestations of the species have been between 4,000 and 6,000 feet (fig. 9).

The only exception was an area in northern New Mexico where grasshoppers expanded westward into adjacent Colfax County during the severe outbreak in Union County in 1937 and 1938. Elevation alone, however, does not explain why the habitat is restricted to such a small area, for the 3,000 to 6,000-foot belt continues for great distances northward and southward beyond the habitat area.

Most of the habitat area lies within the belt that has 15 inches or less average annual rainfall; a very small portion of the habitat extends into the 15- to 20-inch belt, in the eastern part of the Texas Panhandle (fig. 10). In that area, as explained heretofore, the species has not long persisted and has not been of appreciable economic importance. In the area where the species has occurred most frequently and where infestations have persisted longest, that is, in Bent, Crowley, Elbert, El Paso, Las Animas, Lincoln, Otero, and Pueblo Counties, Colo., the annual average precipitation is 13.56 inches, varying from a low of 11.03 inches in Crowley County to 16.20 inches in Las Animas County.

The portion of the habitat next in importance is that in northeastern New Mexico; this portion comprises Union County and parts of Colfax, Harding, and Quay Counties, where the average annual precipitation is 16.29 inches, varying from a low of 14.65 inches in Colfax County to 18.03 inches in Quay County.

Two other areas within the habitat in which outbreaks have been less frequent, of shorter duration, and less destructive than those in Colorado and New Mexico are the Panhandle of Oklahoma and the northwestern portion of the Texas Panhandle. The average normal annual precipitation within that part of Oklahoma comprising Beaver, Cimarron, and Texas Counties is 17.39 inches, varying from a low of 16.49 inches in Texas County to 19.36 inches in Beaver County. The average normal annual precipitation for 2 of the 5 Texas Panhandle counties where the High Plains grasshopper has been of most importance is 19.5 inches. It varies from 18.01 inches in Hartley County to 20.99 inches in Potter County. Weather Bureau records for Dallam, Moore, and Sherman Counties are incomplete.

The portion of the habitat that is in Kansas is in Greeley, Hamilton, Kearny, Stanton, Grant, Morton, Stevens, and Seward Counties. Its average normal annual precipitation is 16.64 inches, varying from 15.85 inches in Stanton County to 17.13 inches in Morton County.

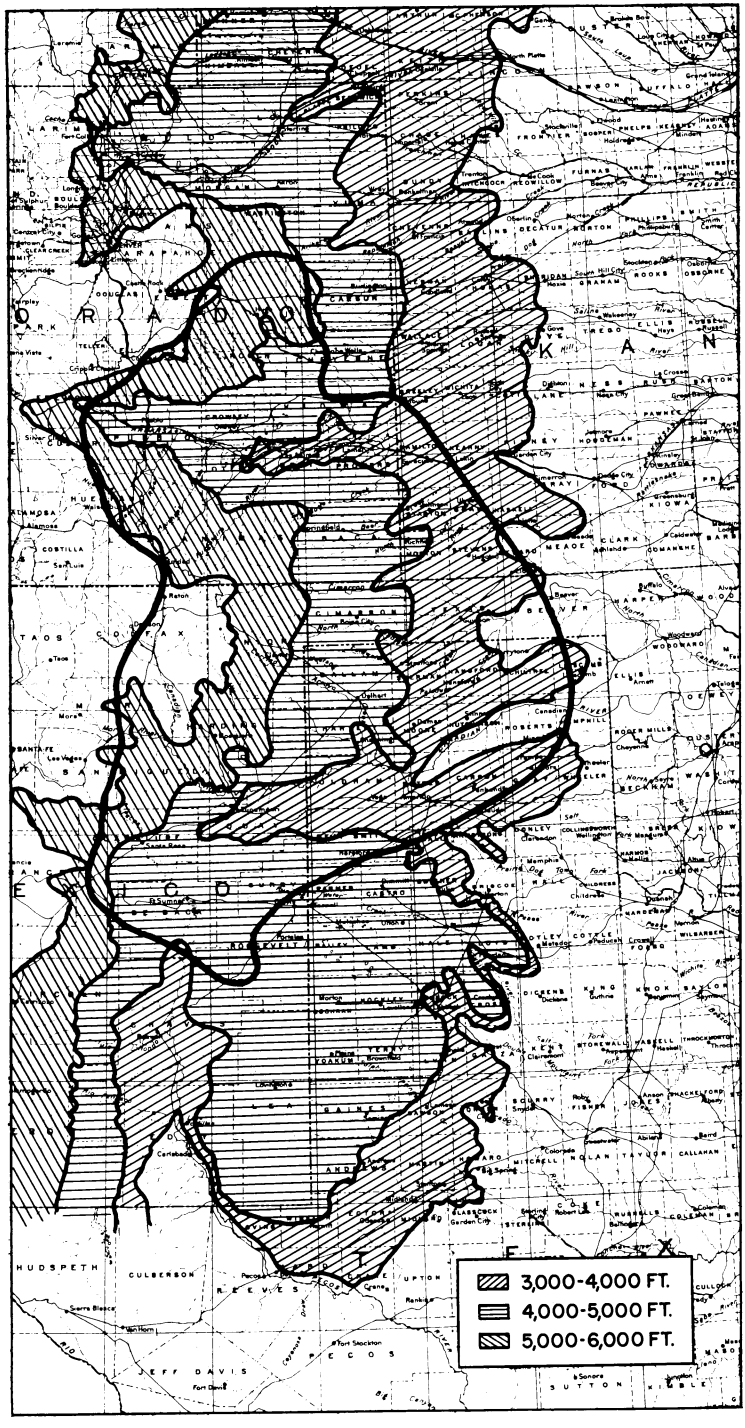


FIGURE 9.—Elevations within the habitat of *longipennis*. [After United States Relief Map *(100)*.]

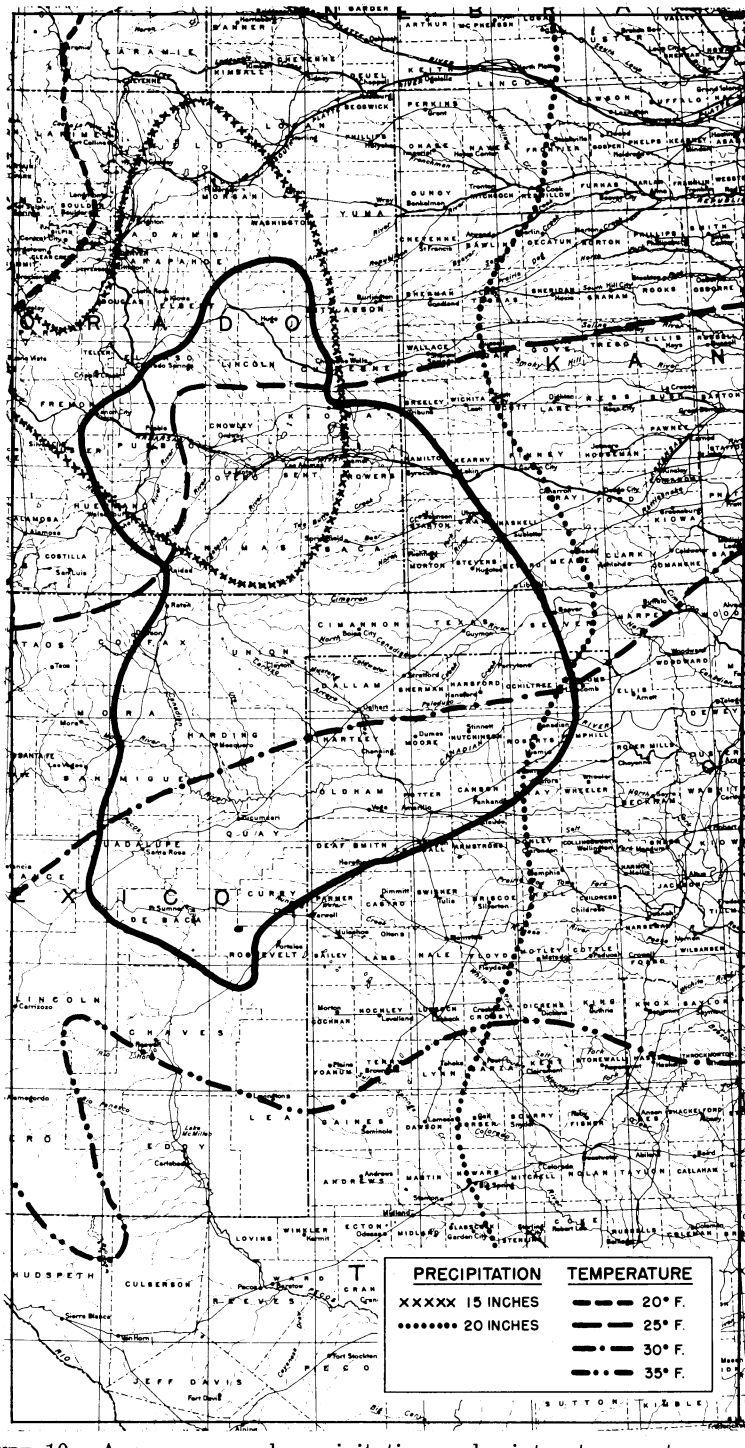


FIGURE 10.—Average annual precipitation and winter temperatures within the habitat of *longipennis*. [After Kincer *(55)*, modified according to current normals for the 20-inch rainfall belt.]

Apparently, the most favorable environment for the survival and reproduction of *longipennis* is a combination of short-grass range, an elevation between 4,000 and 6,000 feet, and an annual precipitation of 15 inches or less. This environment is found in the Colorado and New Mexico portions of the habitat where infestations have been the most frequent and prolonged. One or more of these environmental conditions is lacking in the Kansas, Oklahoma, and Texas portions of the habitat, where infestations have been less frequent and less intensive.

Elevation or precipitation offers no explanation of why the habitat is limited northward and southward. The reason appears to be related to winter temperature. There is no apparent relationship between the pattern of average annual temperature, warm-season temperature, or summer temperature, and the pattern of the habitat area. The possible spring mortality of grasshoppers cannot be discussed in the absence of sufficient research records on the subject. The average winter temperature of the Great Plains, as mapped by Kincer *(55)*, shows that the temperature zones traverse the habitat area in general from east to west. (See fig. 10.) The portion of the habitat that is the most favorable from the standpoint of elevation and precipitation does not extend northward beyond the zone of about 28° F. average winter temperature (December–February) or south of the zone of about 38° F. The effects of winter temperature are not known. It is possible that at the northern limits the eggs of the High Plains grasshopper cannot survive the low temperatures and that at the southern limit, egg mortality results from lack of snow cover, low soil moisture, low humidity, and high evaporation rate, all of which cause desiccation of the eggs.

Summarized below are the elevations, precipitations, and winter temperatures of all portions of the habitat of this grasshopper:

State	Elevation	Annual precipitation		Approximate average winter temperature
		Average	Range	
	Feet	*Inches*	*Inches*	° *F.*
Colorado	4,000–6,000	14.86	11.87 (Pueblo) to—17.55 (Akron).	28–33
Kansas	3,000–4,000	16.64	15.85 (Johnson) to—17.13 (Elkhart).	30–33
New Mexico	4,000–6,000	16.42	14.65 (Springer) to—18.03 (Tucumcari).	33–38
Oklahoma	3,000–5,000	17.48	16.14 (Boise City) to—19.36 (Beaver).	34–38

BIOLOGY

Dissosteira longipennis completes one life cycle annually. Eggs laid in the fall hatch the following spring. Nymphs feed, grow, and migrate by crawling during late spring and early summer. Adults continue to feed, migrate by flight, mate, and lay eggs during late summer and early fall. The dates of egg laying, egg hatching, and transformation of nymphs to adults, and the duration of each metamorphic stage vary from area to area. Within areas, these dates vary from year to year and seasonally with local influences. Influencing factors are climate, topography, elevation, latitude, slope of exposure, and vegetative types.

Comprehensive data on the life cycle of the species are available only for the period when supervisors made observations in connection with control during the 1933-40 outbreak. They are incomplete because supervisors and cooperators could not be present in each locality to record developments. Gleaned from numerous reports, data on the seasonal development of the species have been assembled in table 2.

Workers made numerous records on the biology and habits of *longipennis* during the period. Many records prior to 1939 provide interesting information, but from them it is difficult or impossible to obtain a connected picture of the life pattern and activities of the species. Louis A. Spain and Donald K. Scharff in 1939 had the opportunity, as survey supervisors, to observe habits and developments more closely than control supervisors. Their data as assembled by Spain *(72*)* are drawn on almost entirely for the following account.

Eggs

Eggs are laid mainly in limited areas where egg masses are concentrated in large numbers to form what are commonly known as egg beds. In the fall, an infested area might cover many thousands of acres with here and there an egg bed. Interspersed between egg beds, scattered grasshoppers may deposit individual egg pods.

Eggs are found during the fall and spring in field margins of cropland, grassland, pastures, bottom land, hill land, wasteland, and restoration land. More than 90 percent of them occur in buffalo grass and grama grass range and pasture. A few egg beds may be found in tall grass, weedy grassland, small grain, sorghum and corn stubble, and some in abandoned land. Egg beds are rarely found in non-grasslands.

Egg beds occurred in a variety of topographical and soil conditions, the majority being on exposed slopes in firm, sandy-loam soil. Occasionally they were found in level bottom land and on hilltops. Several egg beds were located in very rocky soil in northeastern New Mexico and southern Colorado. In typical beds in buffalo-grama grass range, egg pods were placed around the edges of the grass plants and in the intervening bare spots. The long, large egg masses were arranged in a nearly horizontal position,

TABLE 2.—Dissosteira longipennis *developmental data*

State and year	Eggs		Nymphs		Adults			
	First eggs laid	Last eggs laid	First emergence	Last emergence	First adult	All in adult stage	First flight	Duration of flight (approximate)
Colorado:								*Days*
1936	Aug. 15	Sept. 30 [1]						
1937	July 25 [1]	Late October.	May 2	June 2	June 27			
1938	July 25	Sept. 1	Apr. 28	Late July	June 22		Late June	[1] 90
1939	Aug. 1	Sept. 1 [1]	Apr. 26 [1]	June 1	June 15	July 10	July 10	
1940			May 6	June 1	June 20	July 6 [1]		
Western Kansas:								
1939						60%, June 17.		
New Mexico:								
1913	Late July	Early September.	May 1 [1]		June 10 [1]			
1937							July 10 [1]	
1938	Aug. 10 [1]		May 1 [1]	May 21 [1]	June 16		June 25	[1] 67
1939	Aug. 1		April 21	June 1 [1]	June 1 [1]	July 1 [1]	June 15 [1]	[1] 97
1940			April 11	May 25 [1]	June 7			
Oklahoma:								
1938	Aug. 25 [1]		May 1 [1]	Late June	July 1 [1]		July 20 [1]	[1] 72
Texas:								
1938	Aug. 25 [1]		May 5 [1]	July 1 [1]	June 19	Aug. 1 [1]		
1939	Aug. 10 [1]		April 22	May 30	June 5			

[1] Approximate.

1 to 2 inches below the soil surface with the upturned froth cap approaching the surface. Eggs within the pod were arranged in almost vertical rows (fig. 11).

In the spring survey in 1939 the number of eggs in 187 egg pods varied from 32 to 84 and averaged 65. Examination of typical egg beds in the spring yielded the following information:

State	Beds examined	Average size of beds	Pods per square foot, average
	Number	*Acres*	*Number*
Colorado	38	25	5.3
New Mexico	23	5	6.3
Texas	14	5	6.6

Egg beds in the *longipennis* habitat ranged in size from one-half to 200 acres and averaged about 15 acres. The egg pod population of 75 beds that were examined ranged from 0.7 to 20 per square foot and averaged nearly 5.8.

Data concerning the hatching period are summarized for 1939 as follows:

State	First hatch	Hatching complete	Average duration of hatching period
			Days
Colorado	May 2	June 1	18
New Mexico	April 21	June 5	23
Texas	April 22	May 30	23

Two egg beds in Colorado were completely hatched 11 days after emergence began. Egg hatching continued for 30 days in one of the most concentrated beds in Guadalupe County, N. Mex. Eggs started to hatch in a number of beds in New Mexico and Texas in late April, influenced by a spell of unseasonable warm weather, but the hatching period was protracted to 23 days of cool weather during the first half of May. In contrast, the same spell of cool weather occurred in Colorado before egg hatching became general. Its influence deferred the date of hatching; however, because weather thereafter was favorable, the hatching period lasted only 18 days.

The pronounced influence of terrain is evident when first hatching dates of beds at high and at low elevations are compared, and when the types of exposures are considered. Eggs at lower elevations, in warm exposures, began to hatch as much as 19 days earlier than some of those on high mesas. One egg bed in Lincoln County, Colo., so situated that it included terrain with both a southern and a northern exposure, exemplifies the effect of a favorable location. At the time hatching on southern slopes was complete only 55 percent of the eggs on northern slopes had hatched.

BN-1041

FIGURE 11.—Egg pods of *longipennis*, showing how eggs are arranged in the pods and the position of egg masses in the soil. (Photo by Colorado State University.)

Nymphs

Normal developmental processes of *longipennis* were so much altered by baiting or by natural factors in 1939 that frequently bands under observation were nearly destroyed; consequently, further records were valueless. Summarized from records that were obtained, the nymphal period was about as follows:

State	First nymphs	First adults	Nymphal period
			Days
Colorado	May 2	June 15	44
New Mexico	April 21	June 5	45
Texas	April 22	June 5	44

In Colorado most of the nymphs passed through 6 growth stages, or instars, but in New Mexico and Texas the majority had only 5. Intermediate between the northern and southern portions of the habitat in Union County, N. Mex., about 50 percent of the nymphs had 6 instars and the remainder 5.

The seasonal development of a typical band of *longipennis* is shown in table 3. Development and activity as given for 1939 may be considered as typical for any year except for variations resulting from the influence of natural factors.

TABLE 3.—*Seasonal development of* Dissosteira longipennis *at Tucumcari, N. Mex., 1939*

Date	Eggs hatched	Instar of nymphs					Adults emerged
		1st	2nd	3rd	4th	5th	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Apr. 29	12	100					
May 1	90	70	30				
15	100	10	25	60	5		
23			5	50	40	5	
June 1				10	65	25	
6					25	65	15
13						50	50
19						10	90
26						2	98
July 5							100

Nymphs gradually dispersed as they fed and grew; with each successive molt the number of nymphs per square yard became fewer. Dispersal appeared to be independent of the influence of control. Baiting abruptly thinned populations, decreasing the size of the bands. Frequently, baiting resulted in the replacement of a large band by several small ones. Populations of bands of first-instar nymphs ranged from a few to a maximum of 2,000 per square yard and averaged about 500. The heaviest population of last-instar nymphs encountered in the southern part of the area was 150 per square yard with an average of less than 50. The average in Colorado was about 100 per square yard.

D. longipennis persisted in bands (figs. 12 and 13) throughout the nymphal period except where populations were too low to become gregarious. Such low populations occurred either naturally or as an effect of baiting. Populations of less than 5 per square yard in new Mexico and Texas and 20 per square yard in Colorado were not observed to band together. This disparity probably represents the range within which nymphs will form into bands, influenced by such factors as nymphal age, vegetation, topography, or weather.

The role of environment in relation to nymphal activity involves many factors. Scharff found that most nymphal feeding was done when the soil-surface temperature was between 80° and 105° F. Spain observed that such feeding was at air temperatures between 74° and 94° F., a range comparable to the range in soil temperatures recorded by Scharff. Nymphs migrated mainly when soil-surface temperatures ranged between 90° and 115° F. Vegetation alone rarely influenced the direction of nymphal migration, for bands frequently moved from areas supporting stands of good grass to areas of poor grass.

Nymphs in some cases remained on the egg beds for more than a week after the eggs hatched. In others, they began to crawl away

BN-1940

FIGURE 12.—Nymphs migrating pictured here on land adjacent to a road in Potter County, Tex.

BN-1939

FIGURE 13.—Nymphs congregated on rocks of an escarpment, Union County, N. Mex.

as soon as they emerged. Migration usually began near the end of the first week after emergence and thereafter increased rapidly. The rate of travel of nymphs was about as follows: First instar, 3 feet per minute; third instar, 6 to 12 feet; and late instar, 10 or more feet per minute. In 1937 Willis *(48*)* found that one band of nymphs had traveled 2½ miles in one day.

The direction of nymphal migrations in 1939 in Colorado was generally slightly west or north, but in New Mexico and Texas no general direction of march was detected as bands were observed moving in all directions during a single day or within one locality. Because bands repeatedly changed directions in New Mexico and Texas they did not travel far, but a few were known to have traveled from 2 to 3 miles from where the eggs had hatched.

Within a week or 10 days after emerging, bands of nymphs often had spread until occupied areas were 10 times or more the size of the original egg beds. For example, nymphs from an egg bed of one-half acre in Texas had spread out over 30 acres in less than 2 weeks; bands of last-instar nymphs in Colorado occupied areas 5 times greater than the egg beds; and fifth-instar nymphs in New Mexico infested areas tenfold the size of the egg beds.

Adults

The first adults (fig. 14) in 1939 were found June 5 in New Mexico and Texas, and June 15 in Colorado. Ninety-eight percent of the nymphs had transformed to adults by July 1 in the former States and by July 15 in the latter. New areas became infested by adults that flew soon after transformation, leaving behind a scattering of nymphs that were molting. Adults dispersed by flying; for a period of 1 month following emergence of the first individuals, adults showed no evidence of the gregariousness exhibited by the nymphs. On first flights adults traveled from 25 to several hundred yards at a time, usually not more than 50 feet above the ground. High, long flights then occurred that dispersed the adults to areas widely separated from those in which they had developed. Dispersing adults frequently were attracted from the

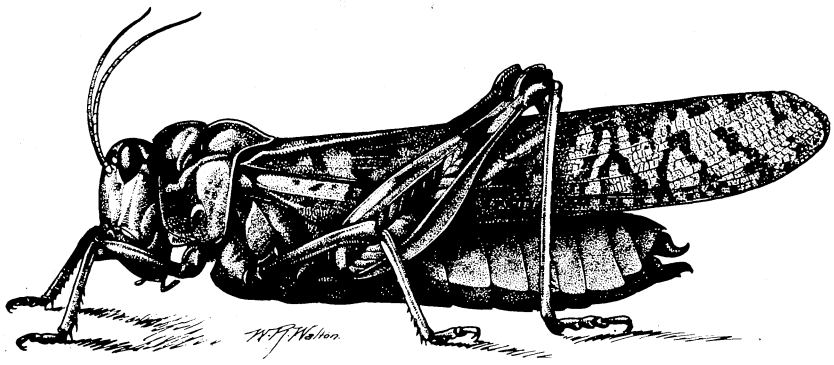


FIGURE 14.—*Dissosteira longipennis.* Adult female, enlarged.

sky at night to the lights of towns. After adults had migrated and alighted on the ground they soon began to congregate. In this process, short, low flights were again observed, and concentration points became potential sites for egg beds. The activity of adults from emergence to oviposition in 1939 is summarized as follows:

State	Emergence of first adults	First congregation	First oviposition
Colorado	June 15	July 16	August 1.
New Mexico	June 5	July 5	July 17.
Texas	June 5	(1)	

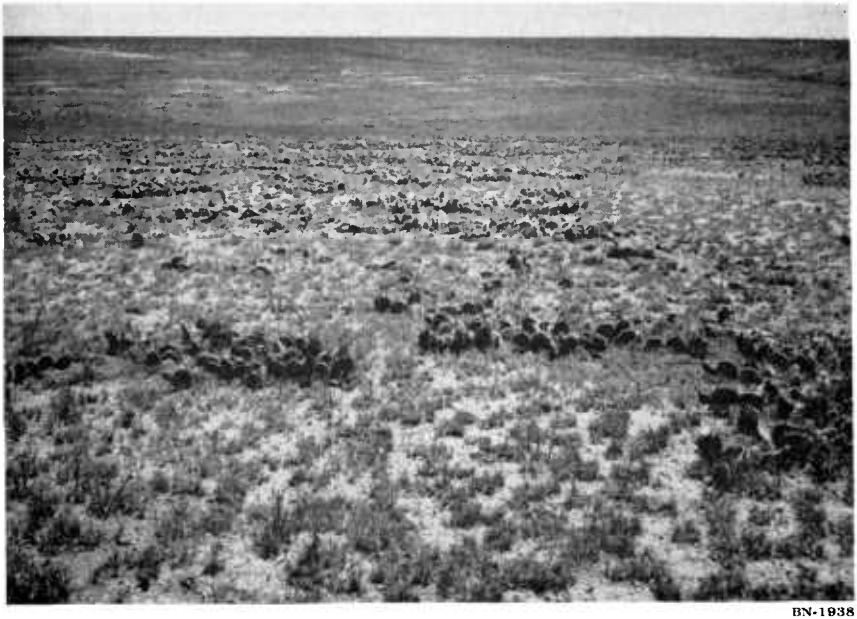
[1] No congregation observed.

Adults became widely and uniformly distributed during the solitary period; they rarely were more numerous than 1 per square yard. An area of 150 square miles in Quay County, N. Mex., which in May contained many concentrated, roving bands of nymphs, had been reduced in population by July 5 to an average of 1 adult per square yard; not more than 2 per square yard were found in any part of the area.

The average population of adults after they had banded for egg laying was about 20 per square yard. Oviposition started 12 to 15 days after adults began to concentrate. Long-distance flights practically ceased when oviposition got under way. In Colorado a gradual movement northward continued at a rate of about 1.5 miles per week during the egg-laying period. The first oviposition was seen July 17 in New Mexico and August 1 in Colorado.

Most of the egg deposition took place between 9 and 12 o'clock in the morning, when the air temperature was between 80° and 90° F. During the early morning, especially at the start of the laying period, females were seen working shallow holes into the soil without distending their abdomens and without depositing eggs. Shortly thereafter females began working holes into the soil with their distended abdomens. Several males gathered around each female and when she withdrew her ovipositor from the soil, mating took place. Sometimes large numbers of holes were made without eggs being deposited. Usually mating occurred on actual egg beds or in areas where eggs were later deposited.

Adult populations on egg beds fluctuated during a day. There was little activity in midafternoon; fewer adults were then on the egg beds than at any other time of day. By 4 or 5 p.m. migrations to the egg beds became very noticeable, and populations increased throughout the late afternoon and early evening. In the mornings adults milled around in low flight with a general movement away from egg beds toward the outer margins of bands where food was more abundant. Most of the gravid females remained on the egg beds until after ovipositing when they, too, abandoned the laying ground. In the low flights to and from egg beds and feeding grounds the grasshoppers moved from ½ mile to 3 miles.



BN-1938

FIGURE 15.—Range denuded of vegetation. Typical appearance of an egg bed.

Egg beds were for the most part placed in friable, sandy soil of grama grass and buffalo grass range, on bare upland exposures free of shrubs. However, several egg beds were found in very rocky soil. Many females exhibited a decided preference for the slightly disturbed soil of tracks made by trucks or bait spreaders.

The appearance of the vegetation aided surveyors in locating egg beds in open grasslands (fig. 15) ; the egg beds were a much darker gray than the surrounding grasslands.

CAUSES OF OUTBREAKS AND OF THEIR SUBSIDENCE

Natural factors, including weather, birds, insect parasites and predators, and animals, affect the ability of *longipennis* to maintain itself continuously in an area or to increase its numbers to outbreak proportions.

Normal weather conditions operate to restrict the habitat to a definite and comparatively limited area. Seasonal periods of weather adverse to the species have reduced infestations and, in isolated instances, have almost wiped out populations in certain areas. Weather unfavorable to grasshopper survival may not occur simultaneously throughout the habitat at the time when grasshopper nymphs are most susceptible to its killing influence.

Birds, because they can quickly reach areas where assembled grasshoppers furnish them with abundant, easily procured food, have probably been the most effective natural enemies.

Insect parasites and predators have made serious inroads on populations of *longipennis* in specific instances. Since it is improbable that many insect enemies accompany this species when it flies long distances from the areas it infested in the spring and summer to the areas where it will deposit its eggs, the extent to which it will be attacked by insect parasites and predators in the area it invades is governed by the chance of location. If it alights in an area where grasshoppers already are present, and where insect enemies have had opportunity to increase, the probability of *longipennis* being attacked by insect parasites and predators is high.

Animal predators, such as rats, mice, and gophers, in some areas have devoured a great many eggs, nymphs, and adults. Doubtless they have destroyed various forms of the species far more extensively than the meager data available indicates. Since the smaller animals are relatively nonmigratory, the degree to which they reduce populations of *longipennis* is directly dependent on the number of grasshoppers that fly into areas already populated by the animals.

The effectiveness of animal enemies was especially pronounced in 1938, 1939, and 1940, when heavily infested areas became progressively smaller as a consequence of control of the species by bait. Then, an increasing population of all natural enemies concentrated on a continuously diminishing population of grasshoppers. There were many instances where grasshoppers that escaped the effects of poisoning were exterminated by their animal enemies.

The adverse weather and animal enemies reduced the amount of baiting planned for in several instances during the 1937-40 period, and in some cases eliminated the necessity for it. They may even have prevented the development of outbreaks in isolated instances. The value of natural factors in reducing the amount of baiting necessary for control of the species cannot be discounted. However, valuable as these controls were, there could be no advance assurance of whether, where, or to what extent, they would operate. Their contribution to control could not be anticipated when control plans were made.

Weather

Outbreaks of *longipennis* have followed periods of drought and have subsided when precipitation was appreciably above normal. Severity, extent, and duration of outbreaks have, in the main, been governed by the duration and severity of drought.

In the absence of biological studies of the species made concurrently with weather observations, the influence of weather has been deduced from temperature and moisture conditions that prevail in outbreak areas during the four outbreaks for which the size of the infested area has been recorded. Three of these, the outbreaks of 1891, 1913, and 1921, were restricted to local areas and lasted only 1 year; the fourth persisted from 1933 to 1940 and covered an extensive area. Moisture conditions influencing the three 1-year outbreaks are shown in tables 4 to 6. Moisture con-

ditions influencing the 1933–40 outbreak are shown in tables 7 to 10; temperature conditions influencing this outbreak are shown in tables 11 to 14.

The outbreak in Lincoln County, Colo., in 1891 (table 4) was preceded by 3 dry years in which precipitation was from 62 to 88 percent of normal. Probably the population of *longipennis* had begun increasing in the early part of this drought period but re-

TABLE 4.—PRECIPITATION IN LINCOLN COUNTY, COLO., 1891 OUTBREAK: *Percentage of normal precipitation in Pueblo, Colo., 1888–92*[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1888	92	108	89	192	40	0	73	36	5	69	126	23	68
1889	89	50	73	127	81	60	45	90	92	231	153	37	88
1890	32	52	69	168	99	41	31	112	3	89	68	51	78
1891	342	15	196	39	169	90	149	42	72	137	38	256	110
1892	50	13	219	75	102	107	178	68	41	283	215	237	125

[1]Average annual precipitation, 91 percent of normal. Precipitation below normal (indicated by shading) in 65 percent of all months.

TABLE 5.—PRECIPITATION IN ROOSEVELT COUNTY, N. MEX., 1913 OUTBREAK: *Percentage of normal precipitation in Portales, N. Mex., 1909-14*[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1909	0	0	107	0	2	114	66	68	38	0	231	141	59
1910	0	0	95	127	73	25	52	173	40	48	42	31	72
1911	56	261	180	134	111	76	49	70	59	145	88	351	111
1912	0	382	14	53	56	72	37	133	175	22	0	56	82
1913	89	226	18	162	38	311	40	36	77	69	337	310	118
1914	41	8	14	73	524	68	144	36	13	211	4	66	133

[1]Average annual precipitation, 96 percent of normal. Precipitation below normal (indicated by shading) 68 percent of all months.

TABLE 6.—PRECIPITATION IN LINCOLN COUNTY, COLO., 1921 OUTBREAK: *Percentage of normal precipitation in Pueblo, Colo., 1916-21*[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1916	58	41	93	163	36	87	46	175	41	101	43	53	83
1917	58	102	63	112	174	41	73	58	433	73	4	7	110
1918	161	165	50	106	3	73	93	32	191	20	140	214	74
1919	8	179	204	188	22	99	163	181	272	45	136	137	136
1920	76	19	21	69	73	34	98	106	177	130	60	88	83
1921	79	15	29	64	57	510	291	126	33	173	153	260	171

[1]Average annual precipitation, 110 percent of normal. Precipitation below normal (indicated by shading) 58 percent of all months.

TABLE 7.—PRECIPITATION IN PRINCIPAL HABITAT, 1933-40 OUTBREAK: *Percentage of normal precipitation in Arriba, Colo., and Clayton, N. Mex., during first 7 years of 1931-40 drought*[1]

Arriba, Colo.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	0	287	213	18	92	187	26	62	16	3	125	50	81
1932	203	3	46	127	56	123	80	28	26	20	2	80	66
1933	3	21	51	207	83	35	114	117	82	3	13	220	92
1934	7	236	24	26	24	41	21	74	26	3	42	4	47
1935	3	113	104	66	215	73	77	71	64	20	35	24	90
1936	21	57	97	32	99	62	61	57	153	106	12	32	73
1937	21	26	103	16	83	93	40	80	90	35	83	86	98

Clayton, N. Mex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	0	118	68	64	93	33	25	123	110	78	7	75	71
1932	158	22	27	61	82	198	25	35	108	45	3	129	67
1933	3	8	3	11	45	64	50	102	5	57	64	3	44
1934	3	123	3	10	19	56	86	83	83	88	86	3	55
1935	273	36	17	3	106	52	51	35	87	22	15	16	58
1936	73	0	0	8	98	31	98	8	33	11	3	44	36
1937	36	13	44	13	189	105	19	14	134	69	16	79	76

[1]Average annual precipitation, 66 percent of normal. Precipitation below normal (indicated by shading) 79 percent of all months in Arriba, and 83 percent of all months in Clayton.

mained unreported until the species created an economic problem by the proportions of the outbreak in 1891. The outbreak apparently did not gain momentum during the year in which it occurred because moisture that year was 110 percent of normal, and it subsided by 1892 when precipitation was 125 percent of normal. For the years 1888 to 1891, inclusive, the average annual precipitation was only 91 percent of normal; 65 percent of all months in that period were below normal in precipitation. At that time the Weather Bureau station nearest the Lincoln County outbreak was at Pueblo in an adjacent county.

The outbreak of 1913 in Roosevelt County, N. Mex. (table 5), originated in 1912. In 1912 the annual precipitation at the Portales station was 82 percent of normal; 9 months of the year were below normal. Probably populations began increasing in 1909 and 1910, when the precipitations were 59 and 72 percent of normal and the increase was interrupted by above-normal precipitation in 1911. The outbreak subsided during the year in which it occurred when the annual moisture was 118 percent of normal, and disappeared by 1914 when the annual precipitation was 133 percent of normal.

The influence of moisture on the 1921 outbreak in Lincoln County, Colo. (table 6), is inconclusive. Although during the year preceding the outbreak the annual precipitation was but 83 percent of normal, the annual precipitation for 5 years had fluctuated yearly from below to above normal. The average annual precipitation for the years 1916 to 1921, inclusive, was 110 percent of

TABLE 8.—PRECIPITATION IN SECONDARY HABITAT, 1933-40 OUTBREAK: *Percentage of normal precipitation in Two Buttes, Colo., Goodwell, Okla., and Dalhart, Tex., during first 7 years of 1931–40 drought* [1]

Two Buttes, Colo.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	9	164	135	85	72	13	6	62	56	73	244	54	55
1932	244	7	116	124	53	194	80	35	60	27	5	43	82
1933	0	9	135	65	71	28	22	180	50	8	120	170	69
1934	44	403	20	29	39	10	16	85	47	81	38	0	57
1935	141	45	39	21	84	11	69	9	173	19	144	41	56
1936	103	15	15	18	100	40	15	31	158	105	2	107	56
1937	53	47	86	29	28	108	27	56	23	85	36	144	52

Goodwell, Okla.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	34	150	335	144	102	61	42	105	66	79	80	136	86
1932	331	83	152	208	81	116	18	62	63	37	29	144	87
1933	4	76	27	53	89	29	49	212	5	41	288	5	75
1934	38	422	44	28	88	85	73	39	127	141	33	26	84
1935	84	70	208	-1	109	85	26	87	34	35	147	21	69
1936	194	9	-1	10	150	29	19	12	136	20	-1	157	51
1937	35	37	97	56	119	79	48	66	83	84	10	33	58

Dalhart, Tex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	87	79	264	126	73	30	100	92	49	51	54	58	81
1932	271	69	73	75	54	311	53	64	101	53	27	162	112
1933	6	26	6	5	28	25	23	216	33	46	21	17	56
1934	-1	52	13	48	57	49	33	27	146	88	51	-1	54
1935	219	3	41	-1	76	58	123	87	117	39	130	15	74
1936	119	2	-1	-1	137	87	63	10	73	4	-1	81	52
1937	39	30	97	47	115	66	46	54	72	52	10	36	64

[1] Average annual precipitation, 69 percent of normal. Precipitation below normal (indicated by shading) 74 percent of all months in Two Buttes, 71 percent of all months in Goodwell, and 81 percent of all months in Dalhart.

normal. In common with the two other local outbreaks discussed, the 1921 outbreak subsided during the year in which it occurred, apparently influenced by the effect of excess moisture. The annual precipitation for 1921 was 171 percent of normal.

The outbreak of 1933–40 was the most severe and extensive of any recorded. Concurrently with that outbreak, drought in the habitat of the species was more severe than for any other similar period. In the habitat area as a whole drought began in 1931 and continued for 10 consecutive years. The population increase of *longipennis* began to be noticeable in 1934, and increased to outbreak proportions by 1936. After 1936 the outbreak annually became larger and more intense until 1940, when it was brought under control by baiting and by natural enemies of the grasshopper.

After the first year, the 1933–40 outbreak showed no similarity to the outbreaks of 1891, 1913, and 1921. Those had subsided quickly, apparently because above-normal precipitation had occurred during the year when populations were increasing to outbreak proportions. No similar phenomenon impeded the outbreak of 1933–40.

TABLE 9.—PRECIPITATION IN MINOR HABITAT, 1933–40 OUTBREAK: *Percentage of normal precipitation in Johnson, Kans., Beaver, Okla., and Spearman, Tex., during first 7 years of 1931–40 drought* [1]

Johnson, Kans.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931		256	158					165			121		
1932	444		159	194		242							
1933			132		161			370			289	313	102
1934		272						108					
1935	170					134					166		
1936	200				164			140				106	
1937						138						109	

Beaver, Okla.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931		196	260	158							234		
1932	393	170	190	126		202						156	100
1933								212					
1934		293	133					141	145				
1935					171			106			151		
1936	211				186				206			135	
1937		185	115					138					

Spearman, Tex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931		221	117				118	112			256		
1932	167			136		285						143	
1933								242			325		
1934		118				115							
1935					197						154		
1936	270				255	164			170			162	106
1937								139					

[1] Average annual precipitation, 77 percent of normal. Precipitation below normal (indicated by shading) 71 percent of all months in Johnson, 70 percent of all months in Beaver, and 75 percent of all months in Spearman.

Although the development of the outbreak was not apparent until 1934, the population of *longipennis* probably began increasing in 1931, the first year of the 10-year drought. The development of the outbreak is mapped in figure 4, facing page 24. The magnitude of the drought is apparent in tables 7, 8, and 9.

Precipitation data, in tables 7, 8, and 9, do not include records for the last 3 years of the 1933–40 outbreak. During 1938, 1939, and 1940, baiting and natural enemies progressively reduced populations of *longipennis* regardless of weather conditions. Precipitation in 1941—nearly doubled the normal (table 10)—could not have affected the outbreak; by then it had already subsided.

The average annual temperature was in excess of normal for 9 of the 10 years of drought in the *longipennis* habitat (table 11). Temperature records are not available for four of the stations in 1930. Since two of these are located where temperature is typically warmer than the average for all stations, it is probable that the 10-year average temperature was above normal.

The severe annual moisture deficiency and the comparatively small increase in average annual temperature during the first 7 drought years are shown in table 15.

TABLE 10.—*Annual precipitation (in inches) at Weather Bureau stations in the* Dissosteira longipennis *habitat during the period 1930-41*

Station	Normal	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
Colorado:													
Arriba	16.30	17.27	13.04	10.71	14.89	6.07	14.58	11.57	10.94	16.66	10.08	13.03	27.60
Two Buttes	15.03	17.95	8.38	13.78	10.40	8.63	8.53	8.46	8.38	15.03	11.29	15.21	31.46
Kansas: Johnson	15.85	21.92	11.26	15.08	16.17	9.38	9.89	10.66	9.26	14.07	9.71	12.61	28.18
New Mexico: Clayton	16.20	18.12	11.45	10.98	7.15	7.24	9.53	5.54	12.03	15.48	13.13	10.99	37.66
Oklahoma:													
Beaver	19.36	15.19	18.46	19.43	10.03	15.40	14.49	15.03	12.61	17.55	14.36	18.59	35.33
Goodwell	16.94	18.53	16.24	14.71	12.62	14.27	11.69	9.69	11.56	14.86	13.64	16.22	26.34
Texas:													
Dalhart	18.01	25.26	14.66	20.09	10.14	9.78	13.31	9.93	14.48	14.08	14.75	12.74	40.91
Spearman	21.26	8.04	20.56	20.20	14.07	13.92	17.32	22.63	16.83	21.99	22.26	20.53	36.27
Average	17.37	17.79	14.26	15.62	11.93	10.59	12.42	11.69	12.01	16.22	13.65	14.99	32.97

TABLE 11.—*Annual average temperature (in degrees) at Weather Bureau stations in the* Dissosteira longipennis *habitat during the period 1930–41*

Station	Normal	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941
Colorado:													
Arriba	48.7	48.4	-------	-------	51.0	-------	48.9	48.9	48.2	52.0	49.2	48.5	48.4
Two Buttes	53.4	-------	-------	-------	-------	57.7	55.9	-------	53.2	54.9	54.2	53.3	55.0
Kansas: Johnson	52.8	54.8	56.2	54.3	57.4	58.8	57.1	56.2	55.8	57.7	57.3	55.0	55.4
New Mexico: Clayton	53.6	-------	53.8	52.7	55.6	56.6	53.8	53.5	53.4	54.4	53.7	53.1	52.6
Oklahoma:													
Beaver	57.4	-------	59.1	57.1	60.3	-------	-------	-------	58.7	60.3	-------	57.7	58.1
Goodwell	56.6	-------	57.0	55.2	58.4	59.5	57.8	57.3	57.8	58.6	58.1	56.5	56.4
Texas:													
Dalhart	54.5	54.4	54.9	53.6	56.7	57.9	55.5	54.9	54.6	55.8	55.0	54.8	54.0
Spearman	57.0	57.6	58.1	55.3	59.8	60.6	57.8	-------	-------	59.1	57.7	56.2	55.5
Average	54.3	53.8	56.5	54.7	57.0	58.5	55.3	54.2	54.5	56.6	55.0	54.4	54.4

TABLE 12.—TEMPERATURE IN PRINCIPAL HABITAT, 1933-40 OUTBREAK: *Percentage of normal temperature in Arriba, Colo., and Clayton, N. Mex., during first 7 years of 1931–40 drought* [1]

Arriba, Colo.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	100	113	85	97	99	104	103	100	100	104	94	98	100
1932	100	114	80	102	104	97	103	102	89	92	100	67	98
1933	116	85	105	94	99	109	103	98	106	108	115	130	105
1934	135	114	100	100	100	107	108	104	95	109	105	107	106
1935	129	110	109	93	87	98	103	103	100	98	93	102	100
1936	97	67	104	101	105	106	105	103	99	92	102	102	100
1937	61	96	91	99	104	98	104	106	103	102	98	99	99

Clayton, N. Mex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	107	106	89	97	95	106	100	98	106	104	106	103	100
1932	88	115	88	102	104	97	103	101	97	98	109	80	99
1933	110	89	106	95	101	106	104	99	106	107	117	127	104
1934	114	108	105	106	109	105	107	105	96	110	114	107	106
1935	119	103	110	101	91	100	102	101	97	99	110	101	101
1936	94	85	107	103	102	103	96	105	98	95	106	102	100
1937	73	97	96	100	104	99	104	106	103	103	105	101	100

[1] Average annual temperature, 101 percent of normal. Temperature above normal (indicated by shading) 52 percent of all months in Arriba and 65 percent of all months in Clayton.

The annual precipitation is not the sole, or even sometimes the chief, criterion of moisture favorable to crop growth. The habitat area of *longipennis* is characterized by flash floods. Local areas may receive excess annual moisture accounted for by torrential rains in one of the summer months, yet be deficient in moisture favorable to plant growth. Little of the excess water is available to plants because of low soil penetration, rapid runoff, and the high rate of evaporation and transpiration.

Summarizing the nature of the precipitation and evaporation of the High Plains, Johnson*(50, pp. 663, 677-678)* says:

> The most effective rains are those which fall slowly and are followed by lingering cloudiness. There is then a maximum ground absorption and a minimum of evaporation. Such rains, as a rule, are widely distributed and occur mainly along recognized "storm tracks." The rains of the High Plains are rarely of this character. The normal "cyclonic" storms cross these uplands in winter only. The summer rains have the character of abrupt, heavy and brief downpours, are local, and have short and erratic courses. They are usually accompanied by hail, and often do damage to crops from this cause, and accomplish only a minimum of good, owing to their violent character in general. Furthermore, though they are of frequent occurrence during the growing season, considered for any large area as a whole, the distribution of moisture is unequal locally, and their wandering and crossing tracks may here and there leave small areas very lightly watered or wholly unvisited.
>
> The High Plains may be taken as very nearly a unit area with respect to evaporation, while to the north of the Kansas-Nebraska boundary there is rapid decrease toward the northeast. Amarillo has an evaporation record of 55.4 inches; Dodge, 54.6 inches; while, in order northward, North Platte has a record of 41.3 inches; Bismarck,

TABLE 13.—TEMPERATURE IN SECONDARY HABITAT, 1933-40 OUTBREAK: *Percentage of normal temperature in Two Buttes, Colo., Goodwell, Okla., and Dalhart, Tex., during first 7 years of 1931–40 drought* [1]

Two Buttes, Colo.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	111	122	100	91	92	104	102	99	110	105	99	111	103
1932	89	100	80	101	105	94	104	102	96	95	100	76	99
1933	112	100	110	97	98	107	103	99	108	103	112	109	105
1934	125	112	103	108	111	107	110	105	98	105	111	114	108
1935	126	115	113	103	92	104	106	103	101	103	99	106	105
1936	102	80	115	100	103	100	104	103	99	94	103	112	101
1937	76	102	93	100	105	99	102	106	102	100	98	96	100

Goodwell, Okla.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	108	112	88	91	94	107	98	97	108	103	97	107	101
1932	93	114	86	98	101	99	104	100	96	95	98	73	98
1933	118	83	104	93	100	110	102	98	107	102	106	123	103
1934	118	104	102	102	106	109	106	105	96	105	106	107	105
1935	120	106	113	96	91	104	104	103	97	103	95	104	102
1936	96	77	109	101	104	108	104	106	99	95	98	110	101
1937	80	103	92	99	105	103	106	107	103	101	98	101	101

Dalhart, Tex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	104	113	86	96	95	104	100	97	108	104	98	108	101
1932	92	118	85	104	104	96	102	101	97	97	99	76	98
1933	111	86	102	95	103	108	105	101	105	104	106	126	104
1934	111	108	100	107	110	107	108	106	97	107	107	111	106
1935	117	109	109	101	92	101	103	102	96	101	95	106	102
1936	95	82	105	101	105	104	102	103	99	96	98	110	101
1937	77	97	90	101	103	100	103	107	103	102	98	102	100

[1] Average annual temperature, 102 percent of normal. Temperature above normal (indicated by shading) 62 percent of all months in Two Buttes, 61 percent of all months in Goodwell, and 64 percent of all months in Dalhart.

31 inches; and St. Vincent, 22.1 inches. Yet at each of these points the precipitation, both annual and during the crop-growing season, is about the same, varying little from 20 inches.

* * * * * * * * * * * *

Summing up, then, in comparing the climate of the High Plains with that of the agricultural northwest, it appears as a matter of scientific record that though the amount of precipitation in the two regions is the same, both annually and during the crop-growing season alone, the High Plains are at a more or less marked disadvantage in that (1) summer rains there are violent and of brief duration, as a rule, rather than gentle and long-continued as they commonly are in the north; (2) secular variation from the normal works greater harm; (3) the normal summer temperature is notably greater; (4) the relative humidity is notably less; (5) there are more hours of sunshine; (6) there is more wind, which, during the summer, is prevailing from the south, is warm, and therefore has a drying effect, whereas during the same season in the northwest the prevailing winds are northerly; and finally (7) it is found that following as an effect of the brief pounding rains, the high temperature, the low relative humidity, the almost uninterrupted sunshine, and the persistent high winds, evaporation is greater in a marked degree.

TABLE 14.—TEMPERATURE IN MINOR HABITAT, 1933-40 OUTBREAK: *Percentage of normal temperature in Johnson, Kans., Beaver, Okla., and Spearman, Tex., during first 7 years of 1931-40 drought*[1]

Johnson, Kans.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	113	119	90	96	95	104	102	97	108	106	100	113	102
1932	93	121	86	103	105	96	105	102	96	95	100	78	99
1933	119	89	108	99	101	107	105	98	107	101	105	126	105
1934	122	107	105	107	111	107	109	106	96	108	111	110	107
1935	124	113	115	100	94	102	107	104	99	102	95	102	105
1936	100	76	109	103	106	105	105	105	100	96	104	114	102
1937	78	103	94	103	107	101	106	108	104	102	97	99	102

Beaver, Okla.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	117	119	87	95	96	106	101	95	110	105	99	116	103
1932	98	119	87	106	103	97	103	99	98	98	108	78	99
1933	123	95	104	98	102	109	104	97	108	102	107	116	105
1934	118	100	98	103	107	109	108	102	95	105	105	100	103
1935	100	100	118	99	91	99	106	100	99	103	93	100	101
1936	100	75	103	103	109	106	105	104	102	97	101	117	103
1937	85	105	96	104	107	100	109	105	103	101	100	103	102

Spearman, Tex.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann.
1931	113	115	91	97	97	104	100	96	109	103	101	110	102
1932	98	110	89	100	99	93	97	98	97	97	100	77	97
1933	123	89	105	98	104	108	103	98	107	102	109	122	105
1934	122	107	106	107	107	105	106	105	98	109	112	106	105
1935	102	102	104	101	92	99	101	103	97	103	94	98	100
1936	95	75	110	108	105	103	102	106	97	88	100	98	99
1937	72	95	89	83	86	101	104	94	85	78	84	100	90

[1]Average annual temperature, 102 percent of normal. Temperature above normal (indicated by shading) 67 percent of all months in Johnson, 58 percent of all months in Beaver, and 51 percent of all months in Spearman.

TABLE 15.—*Extremes of moisture deficiency and temperature excess, 1931–37*

Station	Lowest annual precipitation		Highest average annual temperature	
	Year	Percentage below normal	Year	Percentage above normal
Colorado:				
Arriba	1934	63	1934	6
Two Buttes	1931, 1937	45	1933	9
Kansas: Johnson	1934, 1937	41	1934	7
New Mexico: Clayton	1936	66	1934	6
Oklahoma:				
Beaver	1933	48	1933	5
Goodwell	1936	43	1934	5
Texas:				
Dalhart	1934	46	1934	6
Spearman	1937	41	1934	6

Although temperature excess during the 1931–37 period was, percentagewise, much less than moisture deficiency, it had a profound effect in increasing the rate of evaporation. The combined climatic influence favored growth of the short grasses in areas where they are usually of minor importance. Extension eastward of the short-grass-type range probably favored the eastward spreads of *longipennis* and its temporary establishment in its minor habitat.

Weaver and Clements *(108, pp. 407-408)* describe types of native vegetation as indicators of soil type as follows:

> Short-grass land indicates high run-off and limited water penetration and a growing season shortened by a limited water supply. . . .
> Wire grass indicates soil into which almost all of the rainfall penetrates and where surface evaporation is greatly reduced. The moisture is distributed to a considerable depth and when drought threatens, plants are able to draw on the reserves found in the deeper layers of soil. . . .
> Bunch grass indicates soil of a texture that insures the penetration of practically all of the water that falls. Little water is lost directly by evaporation from the sandy soil. . . . the roots of crops spread widely and deeply and plants rarely wilt because of drought.

The effect of drought and grasshoppers is emphasized by Weaver and Albertson *(107, pp. 225-226)*. In describing causes of damage to range they say:

> Still another factor in reducing the vigor of vegetation was the hordes of grasshoppers which accompanied the drought. For example, from 8 to 15 per square foot were observed during the summer on certain ranges in western Kansas. They ate the leaves and tender stems of the grasses, stripped the foliage of the ubiquitous peppergrass and Russian thistle, and devoured nearly all vegetation including the only plant cover remaining in many pastures—the mat-like *Monolepis nuttalliana*. Even on ranges where stock was excluded, grasshoppers had sometimes eaten practically all of the scanty growth of vegetation. Moreover, buffalo grass was particularly retarded in its development not only by the injury or loss of foliage, but the always hungry grasshoppers cut the stolens at the nodes where they are tender and where the growing tissue is sweet. Thus segregated from the parent plant, the poorly rooted, younger offspring succumbed.

> As a result of the combined forces causing deterioration in range and pasture, there have been marked changes in vegetational structure. The mixed prairie, distinguished by more or less distinct layers of mid grasses and short grasses, has, at least in the several thousand square miles examined, almost entirely been converted into short-grass plains. This has resulted from the loss of the mid grasses. . . .

In later publications the same scientists *(1,3)* stressed again the change that had taken place in range vegetation during the drought. The following is taken from *1, pages 36, 44, 50:*

> the xeric strips of short grasses commonly found on the lower slopes, with bluestems both above and below . . ., became widened by short grasses invading the vegetation both above and below their usual habitat.

> It was the increase in short grasses [at Hays, Kans.] that prevented almost complete destruction of vegetation. In 1934, the cover of buffalo grass and blue grama grass had increased from 20.7 percent to 35.9 percent. A further increase to 42.8 percent occurred by the fall of 1935. This increase was caused by migration

of the short grasses into the portions of the quadrats previously occupied by the bluestems and not by an actual increase in density in the parts which they originally covered.

Drought, overgrazing, and hordes of grasshoppers have caused great reduction in carrying capacity of the range. Yield of palatable forage in overgrazed pastures is less than 10 percent of that produced in well-managed ones. Where 10 to 12 acres was formerly required to sustain one animal unit, 30 to 50 acres are now needed.

The following is from *3, page 462:*

Intense drought alternating with periods of rainfall sufficient to revive the vegetation or even promote vigorous growth characterized a period of 5 years. The net result was a gradual decrease in tall and most mid grasses and less xeric forbs, offset by an increase in short grasses and side-oats grama. A population of annual weeds, although often greatly dwarfed, was characteristic.

* * * * * * * * * * * *

Thus, drought and dust unaided by grazing had reduced a sample area of mixed prairie centuries old to a disclimax of short grasses. . . .

Frequently the effect of weather in local areas has influenced population more importantly than fluctuations in annual precipitation and annual average temperature. The principal reduction in grasshopper populations from weather influences occurs when cold, wet weather persists for several days while the nymphs are in the first-instar stage. The erratic nature of storms during the growing season limits their influence on grasshoppers in the High Plains as a whole. In local areas during certain seasons, weather unfavorable to survival of young nymphs may destroy nearly all of the populations present. Adverse weather has locally affected population of *longipennis* to a greater extent than is generally realized. Prior to the 1933-40 outbreak only one statement has been found on the subject. In his field notes preserved in the National Archives, Harrison E. Smith stated: "Could find absolutely no evidence of recent heavy rains having killed any 'hoppers." This note, dated June 13, 1913, was made when the grasshoppers were largely immune to the effect of weather because they were late-instar nymphs or adults.

Many records on adverse effect of weather, locally, occur in notes and records of survey and control supervisors during the 1933–40 outbreak. Their information is authentic but not complete because each man was assigned to work in a large area. He visited selected locations at intervals throughout the season and recorded population changes but he rarely was present in any locality to detect and record the day-to-day mortality of grasshoppers during any prevailing period of weather. Population reductions of *longipennis* by the effects of weather are cited in the following selections from supervisors' records:

In 1938 Resley *(5*)* reported that cold, cloudy, rainy weather immediately after eggs hatched continued long enough to materially reduce the *longipennis* population in Curry County, N. Mex.

Scharff *(62*)* reported that in 1939 weather had no important effect upon eggs or nymphs in Colorado. He observed only one case where egg mortality from weather influence was greater than 1 percent. In that instance 25 percent of the eggs were hardened

and shriveled in a 3-acre egg bed in Lincoln County where the egg pod population had averaged 5 per square yard.

Spain *(71*, 72*)* after examining numerous eggs before hatching time in the spring of 1939, concluded that weather had not been an important factor in egg mortality in New Mexico and Texas, for in only two cases could it be attributed to effects of weather.

In the control of *longipennis* nymphs by weather in 1939, Spain and Scharff *(72*)* classified the relative effectiveness of weather, birds, and bait as follows:

State	Percentage of nymphs killed by—		
	Weather	Birds	Bait
Colorado			90
New Mexico		5	85
Texas	45	5	45

Spicer *(6*)* reported in 1939 that a period of cold weather in May, just after the emergence of *longipennis* nymphs, had reduced populations countywide in 3 counties and locally in 4 others in the Texas Panhandle. Nymphs appeared in great numbers in Armstrong County, but all were destroyed by subsequent cold weather (maximum daily temperatures did not exceed 65° F.) that lasted a week or longer. Nymphal mortality occurred to some extent in Gray, Carson, Hutchinson, Hansford, Moore, and Oldham Counties.

In some Texas counties nymphs known to be present in the spring of 1939, later so nearly disappeared that plans for control by baiting were abandoned. Spain *(6*)* deduced that weather was the factor responsible. He recorded: "Moore County, May 18—population apparently considerably reduced. No baiting. Moore County, June 2—nymphs reduced more than two-thirds; not enough birds to do this; and deduction was reduction must have been by weather. Randall County, May 24—population much reduced, weather believed responsible. Randall County, June 9—no baiting, infestation reduced 99 percent, probably from effects of two cool, rainy periods in May." He stated that *longipennis* populations in various areas in Oldham, Deaf Smith, Parmer, Castro, Swisher, Briscoe, and Randall Counties in the Texas Panhandle, were observed to dwindle, and these areas became devoid of grasshoppers for no apparent cause. Only a few dead grasshoppers could be found at any one time; birds present lacked capacity for devouring the large number of grasshoppers, and no evidence was found that grasshoppers had been killed by disease or parasites. Because some reductions of nymphs were incorrectly being attributed to baiting activities, the area was checked May 27 to verify locations where bait had been spread. At that time there were fewer nymphs per square yard on ranches where no bait had been spread than there had been hatched eggs per square foot when earlier observations were made. Weather Bureau records at Ama-

rillo showed general rain had fallen during the period May 2 to May 4 and that maximum daily temperatures from May 3 to May 8 had ranged from 70° to 74° F. Another unfavorable weather period had been May 11 to May 15 when maximum daily temperatures were lower than 70° F. for several days and rain was general over the area.

In the extreme southern part of the infested area in 1939, Spain *(6*)* reported that on June 5 the infestation in Swisher County had essentially been wiped out, apparently by weather, with some help from the few birds and other predators present.

Scharff *(57*)* reported May 5, 1940, that in several egg beds in Lincoln County, Colo., where egg concentrations were light, 90 percent of the eggs had been killed by drought or mold. He expressed the belief that for the infested area in Colorado as a whole, the influence of adverse weather had reduced by 40 percent the population expected in the State. At the same time he discounted the overall effectiveness of natural influences, and expressed the conviction that the remaining population of grasshoppers was so heavy that the bait-control program should not be affected.

On June 8, 1940, he reported that natural control had been an important factor in population reductions in Pueblo, Otero, and Las Animas Counties, Colo., and that several egg beds in Otero County's populations were so cut down that baiting was not necessary. He listed adverse weather during the hatching period as one of the chief agents contributing to this natural control.

At the end of the season he said: "Weather was an important factor . . . in southern Colorado in the control of *longipennis*. . . . Cold, rainy days, lasting from 1 to 3 weeks during the height of the hatching period, apparently resulted in starvation of the newly-hatched nymphs because low temperatures prevented their active feeding. . . . Complete disappearance of nymphs occurred on many egg beds before development had reached the third instar. In Lincoln County, Colo., the northern edge of the infested area, weather conditions during and after the hatch were favorable, with temperatures above 70 degrees for at least part of most days, and weather conditions played practically no part in control of the hoppers there."

On May 24, 1940, he reported that adverse weather, together with bird activity, occurring as it did at the height of the hatching period, resulted in population reductions of as much as 50 percent in De Baca and Chaves Counties and in the Quay area of Quay County, N. Mex.

Weather undoubtedly has been chiefly responsible for stopping the development of many outbreaks locally, but available records do not indicate that it has operated effectively to reduce simultaneously populations of *longipennis* in its habitat areas as a whole. The effect of the timing of local unfavorable weather with respect to the stage of development of the species is illustrated by an occurrence in 1939. When the first-instar nymphs were killed by prolonged cool, wet weather in the Texas Panhandle, similar weather prevailed in Colorado. At that time, however, eggs were not yet hatched in Colorado, so the unfavorable weather operated

merely to delay the hatch until the weather warmed up again. When nymphs appeared they developed through the critical period without mishap.

Climatic patterns favorable and unfavorable to the survival and maintenance of *longipennis,* prepared into climographs as described by Cook *(27),* are shown in figures 16-23. Figures 16-18 depict normal temperature and precipitation within the *longipennis* habitat (unshaded climographs) and average temperature and precipitation within the *longipennis* habitat during the drought years 1931–37 (shaded climographs).

The habitat area is characterized by low precipitation during the winter months and the greatest amount of precipitation in late spring and summer. Average monthly temperatures are above 30° F. in January and do not exceed 80° in July. Average temperature and precipitation for the period 1931–37 was of the same pattern as normal temperature and precipitation except that in general the temperature was higher and the precipitation less.

Five locations outside the habitat of *longipennis* were selected for comparisons of climatic pattern with that within the habitat.

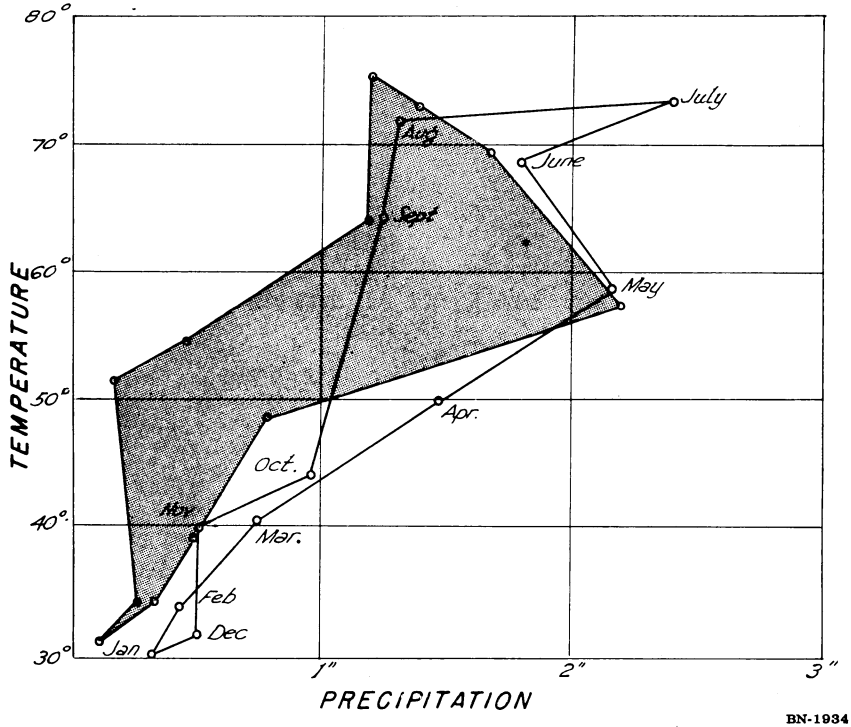


FIGURE 16.—Climographs for the principal habitat of *longipennis,* comparing normal climate (unshaded) with climate for 7 drought years (shaded). Unshaded climograph prepared from average normal monthly mean temperatures and average normal monthly precipitations at U. S. Weather Bureau stations at Arriba, Colo., and Clayton, N. Mex. Shaded climograph prepared from average monthly mean temperatures and average monthly precipitations at the same stations during the years 1931-37.

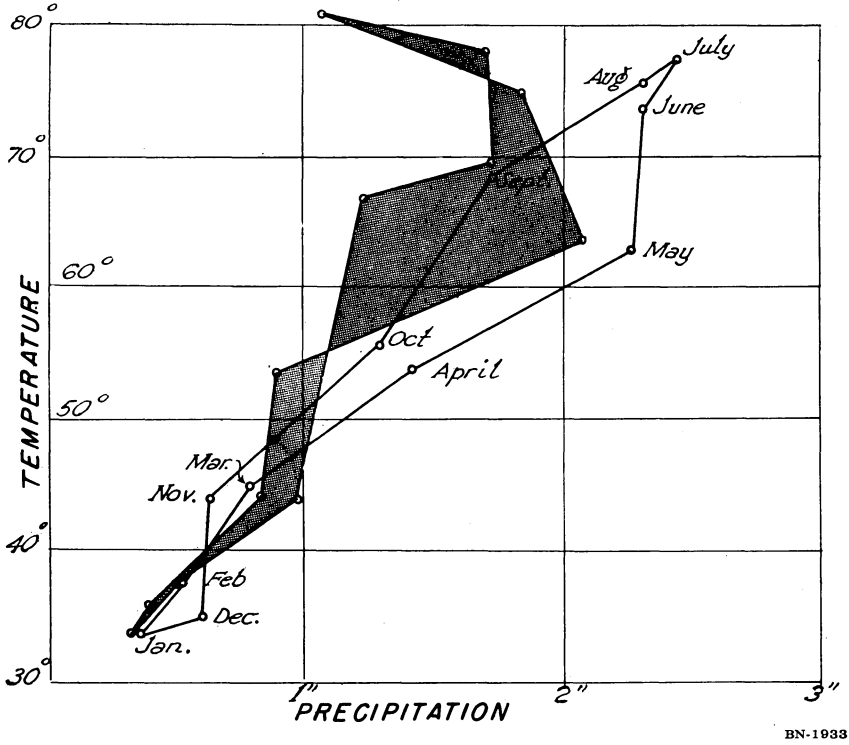


FIGURE 17.—Climographs for the secondary habitat of *longipennis*, comparing normal climate (unshaded) with that for 7 drought years 1931–37 (shaded). Data from weather stations at Two Buttes, Colo., Goodwell, Okla., and Dalhart, Tex.

Three of these locations were chosen because the Weather Bureau stations were at approximately the same elevation as the station within the habitat, with which comparison was made. Two were selected because the stations were at approximately the same latitude.

Comparisons of stations at the same elevation are shown in figures 19–21. Albuquerque, N. Mex., which is near to and west of the habitat area, has a temperature pattern quite similar to that of Clayton, N. Mex., which is within the principal habitat area. However, moisture patterns are similar only during the winter months.

The climatic pattern of Lead, S. Dak., outside of the habitat area, does not differ markedly with respect to temperature from that of Arriba, Colo., within the principal habitat area. With respect to precipitation, however, the climatic patterns are quite dissimilar; the rainfall at Lead appreciably exceeds that at Arriba for every month of the year except August.

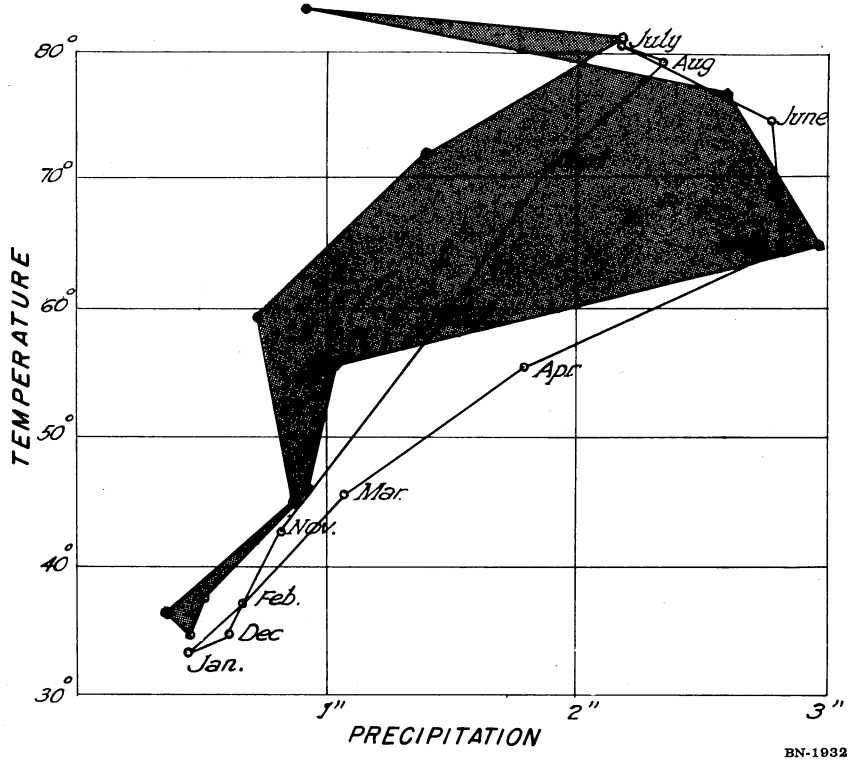


FIGURE 18.—Climographs for minor habitat of *longipennis*, comparing normal climate (unshaded) with climate for 7 drought years 1931–37 (shaded). Data from weather stations at Johnson, Kans., Beaver, Okla., and Spearman, Tex.

While climographs for Albuquerque, N. Mex., and Lead, S. Dak., represent localities with climatic patterns similar in one respect to climatic patterns within the habitat but dissimilar in the other respect, the climatic pattern at Sheridan, Wyo., is dissimilar in both. Sheridan, outside of the habitat, and Boise City, Okla., within the secondary habitat, are at elevations approximately the same, but the average temperature is markedly lower every month at Sheridan. Total annual precipitation is only slightly less at Sheridan than at Boise City but a much larger proportion of it falls during the winter months.

Comparisons of stations at the same latitude are shown in figures 22 and 23. Woodward, east of the habitat area, has a warmer and wetter climate throughout the year than Clayton, which is within the principal habitat. On the other hand, Cimarron, west of the habitat area, has, in general, a cooler and drier climate throughout the year.

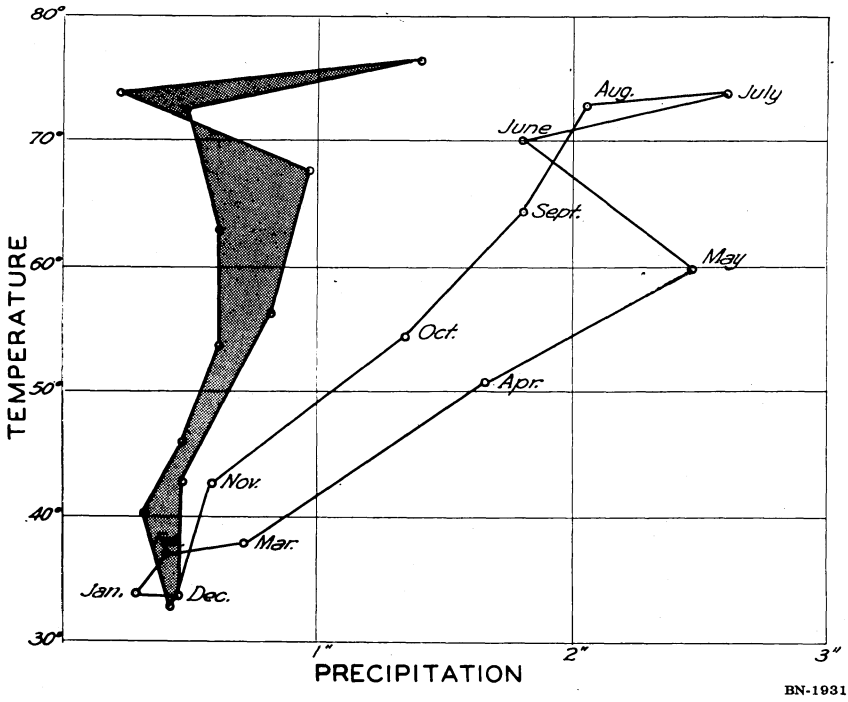


FIGURE 19.—Climographs for Clayton, N. Mex. (unshaded), and Albuquerque, N. Mex. (shaded). Both locations are at approximately the same altitude and have similar temperature patterns, but moisture patterns are dissimilar during most of the year. Clayton, within the habitat of *longipennis*, has an elevation of 5,054 feet. Albuquerque, outside the habitat, has an elevation of 5,130 feet.

Natural Enemies

Insect Parasites

Publications on *longipennis* prior to 1897 made no reference to the occurrence of insect enemies of the species. Popenoe's abstracted report *(68)* stated *(p. 41)*: "Many dead ones were noticed in one locality [of northern Lincoln County, Colo.], but no signs of parasitism were found. It is supposed that they were destroyed by hail." Following this report there is a notation *(p. 42)* that [Bruner] "had also seen the dead locusts in one locality in eastern Colorado and considered that they had been killed by hail."

Bruner *(19, pp. 38-39)* reported in 1897 that: "One very encouraging feature connected with this insect, in the vicinity of Sidney at least, was the presence in large numbers of a peculiar long-legged Tachina fly that apparently attacked and destroyed many of the locusts. So numerous was this fly that with favoring circumstances it must soon reduce the 'hoppers to normal."

Smith *(87, pp. 7-9)*, in 1913, recorded that: "A Dipteron, *Sarcophaga kellyi* Ald., was found to be by far the most important

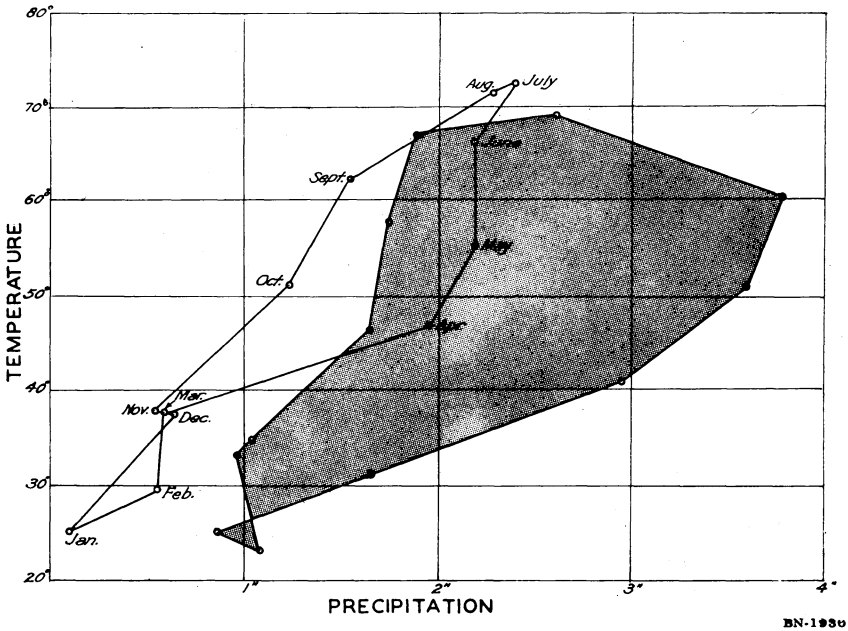


FIGURE 20.—Climographs for Arriba, Colo. (unshaded), and Lead, S. Dak. (shaded). Both locations are at approximately the same altitude and have similar temperature patterns; moisture patterns are markedly dissimilar. Arriba, within the habitat of *longipennis*, has an elevation of 5,248 feet. Lead, outside the habitat, has an elevation of 5,243 feet.

factor in the control of this species, and it was equally efficient as a parasite upon both the nymphs and adults." "During the latter part of June the grasshoppers were enormously reduced in numbers from parasitism by *S. kellyi*. It was a simple matter to count 15 or more dead grasshoppers to the square foot over large areas. The grasshoppers died in such numbers in some localities that ranchers informed the writer that certain droves were almost completely destroyed." "On June 16 a female of *S. kellyi* was noted to deposit tiny maggots on the dorsum of the thorax (pronotum) of a freshly molted nymph." "The number of living maggots deposited by the female upon an individual host during one period of larviposition would vary from 1 to 7 or more, although from 3 to 6 appeared to be the more general." "*Sarcophaga kellyi* is a plural-brooded species, several generations occurring during the season. At least two and probably three generations went through to maturity as parasites of *D. longipennis* from early May to the middle of July."

Shotwell *(64*)* found heavy parasitism of *longipennis* in Bent County, Colo., in 1938 and in some parts of Cheyenne County, where it ranged from 5 to 60 percent in various localities.

Hildwein *(19*)* reported that: "During the fall of 1938 a tremendous amount of parasitism of adult hoppers by flesh flies occurred. In one place in Union County [N. Mex.] 80 percent of

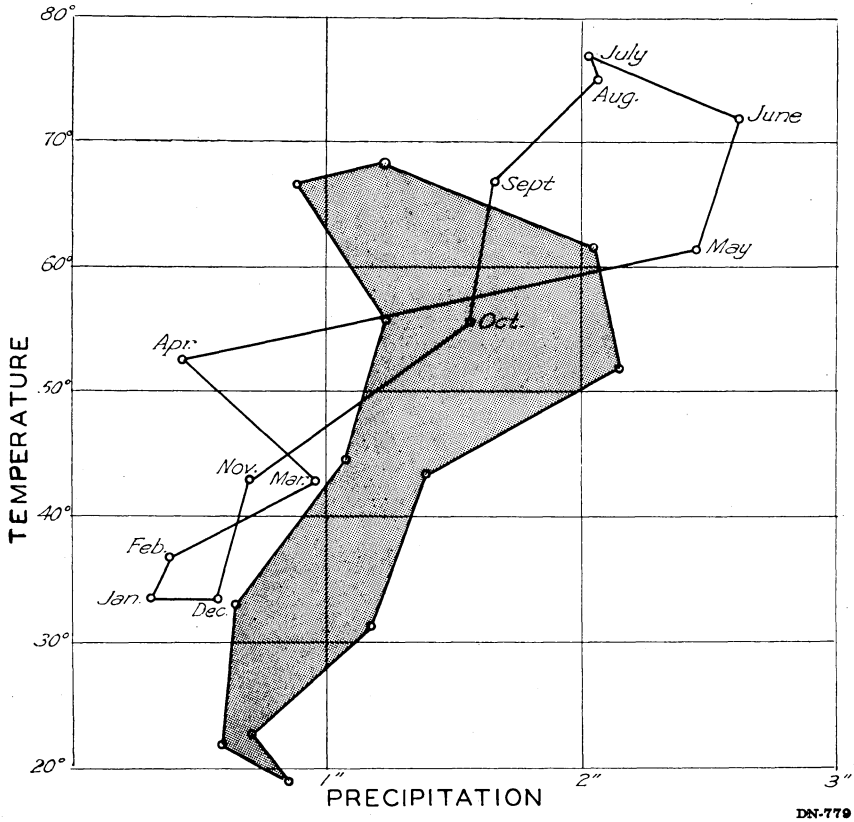


FIGURE 21.—Climographs for Boise City, Okla. (unshaded), and Sheridan, Wyo. (shaded). Both locations are at approximately the same altitude, but temperature patterns and moisture patterns are dissimilar. Boise City, within the *longipennis* habitat, has an elevation of 4,000 feet. Sheridan, outside the habitat, has an elevation of 4,021 feet.

the females taken were found to be the host of these flies. On September 9 the writer, in company with Dr. George Decker, noted heavy infestations of flesh fly larvae in grasshoppers in Quay County." The importance of parasitism in Union County that year was further emphasized by Kurtz *(5*)*, who said: "The adults were very badly infested by sarcophagid larvae that caused many to die either before or after the first deposit of eggs." In New Mexico also, Landrum *(31*)* reported "there is a tremendous amount of parasitism of adult 'hoppers by flesh flies. In one place in Union County 80 percent of the females taken were found to be the host of the larvae of these flies."

Kropf *(29*)*, in 1938, recorded parasitism by sarcophagid flies in several Colorado counties.

According to Davis and Mickle *(3*)* sarcophagid and tachinid flies were observed in large numbers during the latter part of the summer in Colorado in 1939 although few parasitized grasshoppers were found before the beginning of the egg-laying period.

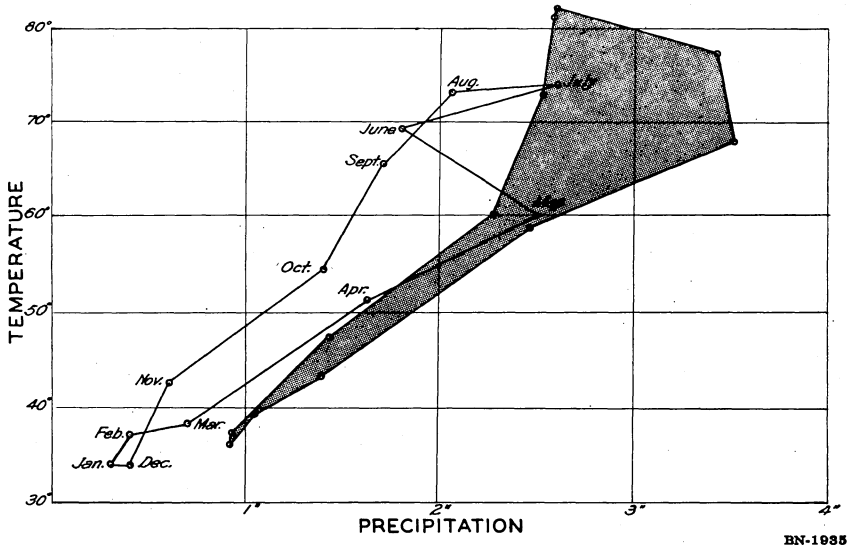


FIGURE 22.—Climographs for Clayton, N. Mex. (unshaded), and Woodward, Okla. (shaded). Both locations are at the same latitude, 36°27′ N. Woodward, outside the *longipennis* habitat, has higher temperatures and more moisture throughout the year than Clayton, which is within the habitat.

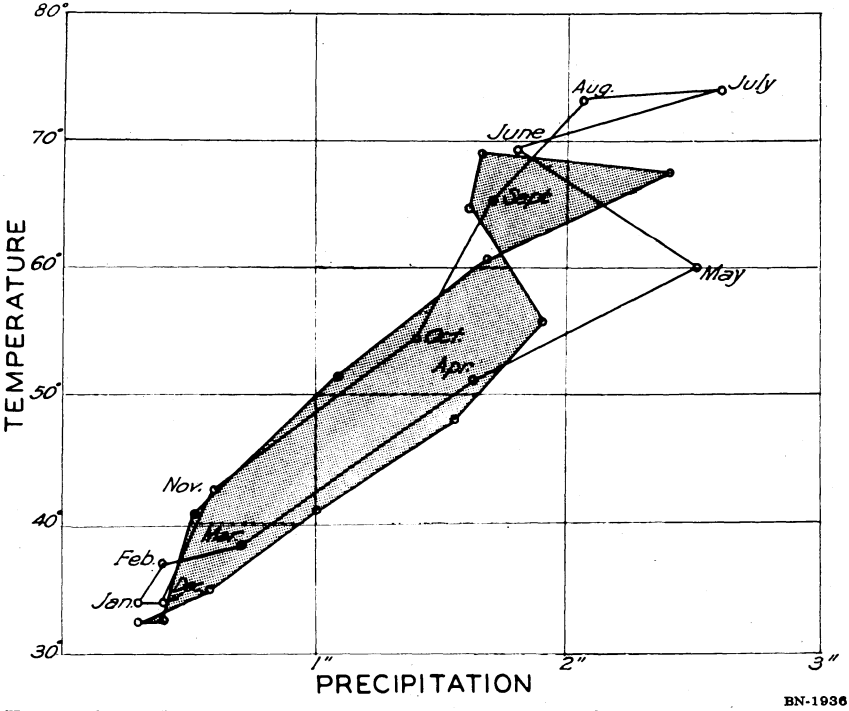


FIGURE 23.—Climographs for Clayton, N. Mex. (unshaded), and Cimarron, N. Mex. (shaded). Both locations are at approximately the same latitude. Cimarron, outside the *longipennis* habitat, has lower temperatures and less moisture throughout the year than Clayton, which is within the habitat. Latitude of Cimarron is 36°31′ N; latitude of Clayton is 36°27′ N.

Parasitism of *longipennis* did not exceed 10 percent in any case observed and rarely reached that proportion. The grasshoppers became infested after they had reached the adult stage. The average amount of parasitism was about 3 percent.

Scharff *(72*)* in his report on Colorado for 1939 said: "Throughout the adult period, sarcophagid parasitism averaged from 2 to 4 percent of the total *longipennis* population. I found as many as 15 maggots in one female 'hopper. . . . More than twice as many males as females were examined for parasites, but out of 1800 grasshoppers examined only 4 males were found parasitized, each with 1 sarcophagid larva."

Spain *(72*)* determined that sarcophagid parasitism in New Mexico in 1939 averaged between 2 and 3 percent. Sarcophagid adults were very numerous at three distinct times in the season, an indication that the species passed through at least three generations. Although the cumulative effect of sarcophagid parasitism is not easily estimated, he reasoned that it greatly exceeded the average parasitism observable. Less than 1 percent of the parasitized grasshoppers examined were males; parasitism in individual localities reached as high as 15 percent. Several last-instar nymphs had been attacked by flesh flies, and as many as 18 larvae were found in a single adult female *longipennis*.

On June 23, 1940, Scharff *(57*)* found that sarcophagids had been parasitizing sixth-instar nymphs in Colorado. The number parasitized in some cases accounted for 10 percent of the total *longipennis* population.

Insect Predators

Smith *(87, p. 9)* said of the 1913 infestation in Roosevelt County, N. Mex.: "Second in importance as a controlling factor of *D. longipennis* was the preying upon the nymphs by the sphecid wasps *Prionyx atrata* Lep." "Being very diligent workers, apparently working from sunrise to sunset during favorable weather conditions, the number of the grasshoppers were greatly depleted from their efforts."

Insect predatism in Colorado in 1938 was seldom recorded. One report in Baca County *(6*)*, August 31, said: "Carabid and Meloid larvae are attacking *longipennis* egg beds. At present 25 percent of the egg pods are so attacked." Another report in Bent County, November 1, read: "Heavy percent of predatism is evident."

Shotwell reported *(64*)* that in New Mexico in 1938: "Egg predators played an important part in reducing egg populations in many of the *D. longipennis* egg beds."

Kurtz, the county agent, had the following to say about insect predators in Union County, N. Mex., in 1938 *(5*)*: "The agent, with Mr. Landrum, has made a few hasty trips to the northern and western parts of the county to see what the number of eggs in these beds might be. In instances where the ground has been perforated like a sieve, egg pods could not be found. In quite a number of instances bee-fly larvae and blister beetles were found

in the beds. Where they were found, many egg shells or remnants of egg pods were found."

Landrum *(64*)* reported that in 1938 in San Miguel County, N. Mex., there was evidence of considerable work by predators on egg beds in the Conchas area. Blister beetle and Carabid larvae had done considerable digging. During the same year Moore *(5*)* found bee-fly larvae and blister-beetle larvae at the rate of one each per square foot in egg beds in Cimarron County, Okla.

Kropf *(29*)*, in 1938, recorded bee-fly and blister-beetle larvae attacking the eggs of *longipennis* in several Colorado counties and several instances where he observed tiger beetles and ground beetles killing first- and second-instar nymphs, 2 species of predaceous wasps which attacked late-instar nymphs and adults, and 3 species of robber flies that preyed upon late-instar nymphs.

Mickle and Kropf *(3*)* in 1939 found egg bed areas of *longipennis* in Colorado where bee-fly larvae averaged as high as 15 per square foot.

Scharff *(72*)* in Colorado in 1939 found that "egg predators, chiefly bee flies, vary greatly in numbers on different egg beds, even in the same infested area, ranging from 0 to 15 per square foot. About 17 percent of all pods found were wholly or partly destroyed by these predators [birds, animals, insects]." He summarized the data on the effect of insect predators alone as shown in table 16. Partly destroyed pods were considered as wholly destroyed in calculating the percentage of pods destroyed.

He observed a predaceous wasp attacking *longipennis* adults and described its activity as follows: "The Bembecid wasp, *Stizus unicinctus*, averaged about one per square rod on congregated *longipennis* in Colorado this season. It was observed to strike one or several flying 'hoppers in succession, apparently knocking them several inches, sometimes causing them to alight; then it would go on, seeking further prey. . . . One of these wasps was found covering its burrow in typical digger wasp fashion. Excavating the burrow, I found a parasitized male *longipennis* with an egg firmly attached. . . ."

In New Mexico in 1939 Hildwein *(20*)* reported that: "During the fall and early spring it was found that a great number of beetles and maggots were working in the egg beds."

Spain and Scharff's estimates *(72*)* of predatism from the time *longipennis* eggs were laid in 1938 until hatching time in 1939 are summarized as follows:

State	Egg beds surveyed	Average size of egg beds	Egg pods per square foot	Reduction by predators
	Number	*Acres*	*Number*	*Percent*
Colorado	38	25	5.3	9.6
New Mexico	23	5	6.3	15.0
Texas	14	5	6.6	10.0

TABLE 16.—*Influence of insect predators upon eggs of* Dissosteira longipennis *in Colorado as determined by survey in the spring of 1939*

Survey stop No.	Egg pods per square foot			Percent of pods destroyed
	Undamaged	Partly destroyed	Destroyed	
1	0.7	0	0	0
2	7.0	1.1	2.4	33.3
3	8.0	1.1	0.8	19.2
4	7.7	1.9	1.0	27.4
5	9.0	1.0	0.2	11.8
12	3.0	1.0	0	25.0
14	4.5	0	0	0
15	5.8	0.2	0	33.3
16	4.3	0	0	0
17	2.7	0	0	0
18	3.6	0.6	0	14.3
19	4.3	0.3	0.4	14.0
20	3.6	0	0.1	2.7
25	8.4	1.6	0.9	22.9
28	4.7	0.8	0.7	24.2
28	7.4	1.0	0.4	15.9
29	2.8	0.3	0.3	17.6
32	5.1	0.2	0.5	12.1
33	6.9	0.2	0.1	4.2
33	8.1	1.4	0.3	17.3
34	8.4	0.5	0.4	9.7
35	9.0	0.9	1.5	21.1
35	9.2	1.3	0.7	19.6
37	4.9	0.9	1.1	29.0
38	6.2	0.1	0	1.6
49	0.8	0	0	0
50	3.0	0	0	0
52	5.2	0	0	0
53	4.8	0.1	0.1	4.0
53	1.0	0	0	0
54	5.7	0.1	0	1.7
56	3.6	0	0	0
57	9.5	2.2	1.2	26.4
58	2.3	0	0	0
59	5.5	0	0	0
60	5.0	0.1	0	2.0
62	3.4	0.1	0	2.9
63	6.4	0.1	0	1.5
Average	5.3	0.5	0.34	10.9

They said further: "The reduction of egg pods by predators (bee-fly, blister-beetle and Carabid larvae, birds and animals) averaged about 11 percent although predatory reduction was of a different type in Colorado from that in the southern part of the area. Egg predators per square foot for the 38 stops in Colorado averaged as follows: Bee fly, 2.1; blister beetle, 0.7; Carabid, 0.03. In some beds no predaceous larvae were found, whereas in one 3-acre bed there were 19.7 bee-fly and 3.1 blister-beetle larvae per square foot.

"In Texas and New Mexico, blister-beetle and Carabid larvae were seldom found, as indicated by a reduction of egg pods estimated at less than 1 percent. Birds and rodents, principally western horned larks, rats, mice, and gophers, were believed to destroy 15 percent of the *longipennis* pods in the egg beds of New Mexico and 10 percent in Texas."

Small Animals

Shotwell *(64*)* found in New Mexico in 1938 that: "Rodents played an important part in reducing egg populations in many of the *D. longipennis* egg beds."

Landrum *(64*)* reported that in New Mexico in 1938 predators had done considerable excavating in egg beds in the Curvo area of Guadalupe County. In that case rats seemed to be more important than other predators. He found one 5-acre egg bed in Quay County that had been heavily worked and observed that rats had done considerable digging in one spot in the Conchas area of San Miguel County.

Kropf *(29*)* live-trapped rodents which he saw feeding on *longipennis* or which he suspected as being predaceous. He found recognizable remains of grasshopper bodies in the burrows of the Kangaroo rat *(Dipodomys ordii richardsoni)*, the plains pocket mouse *(Perognathus flavescens)*, the Kansas pocket mouse *(P. hispidus paradoxus)*, the striped ground squirrel *(Citellus tridecemlineatus alleni)*, and the wood rats *(Neotoma floridana baileyi* and *N. albigula warreni)*. He also observed that when adults of *longipennis* migrated through the towns of the plains prairie dog, the prairie dogs fed upon them greedily. By examining animal dung during 1938–40 he determined that the following animals had fed to a greater or lesser extent upon nymphs and adults of *longipennis*: Striped skunk, badger, bob cat, kit fox, and coyote.

Scharff *(72*)* said in 1939 that: "Examination of fecal matter from skunks and coyotes shows that these two predators fed almost exclusively, for a time at least, on *D. longipennis* adults in some areas."

Davis and Mickle *(3*)* for Colorado in 1939 said that: "Aiding the birds are sand rats, pocket gophers, skunks, and small rodents found on the prairie where the egg beds are located."

Spain *(72*)* found that in New Mexico in 1939: "Bird and animal activity was generally in direct proportion to the egg populations. The cumulative effect of feeding from oviposition time through open periods of winter until hatching time was important but in no case was it sufficient to eliminate the need for control." He estimated that rats, mice, and gophers helped destroy 15 percent of the egg pods in Texas and New Mexico in 1939.

Reptiles

Doubtless many species of reptiles devoured *longipennis* nymphs and excavated eggs, particularly in the southwestern portion of the habitat but only two specific references to that subject have

been found. Smith *(87, p. 7)* said of the 1913 infestation of *longipennis* in Roosevelt County, N. Mex.: "Several species of lizards, which were very numerous in this locality, fed voraciously upon nymphs. Oftentimes lizards were noted so bloated from grasshopper feeding that travel was accomplished only with great difficulty. Horned toads were also heavy feeders upon the immature grasshoppers."

Kropf *(29*)* observed two species of lizards and a horned toad that fed greedily upon first-instar nymphs as they emerged from the eggs. In the stomachs of snakes he found *longipennis* remains of all stages from first-instar nymphs to adults. Those posted were bull snakes, hog-nosed snakes, and rattlesnakes. He found 14 adults in the stomach of one rattlesnake.

Birds

Smith *(87, pp. 6-7)* said of the 1913 infestation in Roosevelt County, N. Mex.: "Among the more important bird enemies noted to be feeding upon grasshoppers during this invasion were the desert horned lark . . ., western meadowlark . . ., desert sparrow hawk . . ., nighthawk . . ., killdeer . . ., and quail . . ."

Although Kropf *(29*)* recorded the desert horned lark and lark bunting as the most important bird predators, he observed shrikes feeding heavily upon adults late in the summer, curlews carrying adults to their young, and killdeers devouring the grasshoppers when their migrations carried them close to ponds or moist areas.

Shotwell *(64*)* said that in 1938: "Birds played an important part in reducing egg populations in many *D. longipennis* egg beds."

Landrum *(64*)* reported in 1938 that one egg bed of 5 acres in Quay County, N. Mex., had been heavily worked by birds, that in another instance evidence that birds were feeding on *longipennis* eggs was pronounced and that birds were excavating eggs throughout an eggbed comprising 150 acres.

Many references to the effectiveness of horned larks and lark buntings in destroying eggs, and to some extent nymphs of *longipennis,* are found in reports of survey and control supervisors during the latter part of the 1933–40 outbreak. Resley *(5*)* said of New Mexico in 1938: "Of importance not to be minimized was the part played by predators. These were chiefly western horned larks and lark buntings. In areas where baiting had secured kills of 90 to 95 percent, these two species of birds were responsible in cleaning up residual populations to the point where they were hardly existent."

Olds *(6*)* reported for the area of Texas in which he worked in 1938 as follows: "Although Sherman County was heavily infested with *D. longipennis* in 1938, no outbreak occurred this year. During the hatching period one egg bed was observed which was never baited because the lark bunting completely controlled the nymphs." Of the same area Spicer *(6*)* said flocks of lark buntings caused considerable destruction to *longipennis* nymphs throughout the spring.

Davis and Mickle *(3*)*, after describing predatism by hawks which fed on grasshoppers in Colorado in 1939, said: "Other birds, such as the horned lark, have added materially to the reduction of next year's infestation, not so much from the destruction of live 'hoppers as from destruction of the egg pods."

In Colorado in the spring of 1939 Scharff *(72*)* found that: "Western [desert] horned larks were a slight factor in reducing egg pod numbers, taking possibly 1 percent of the egg pods laid. The extent of their effectiveness, however, is very difficult to determine, because of the rapidity at which their excavations were obliterated by weather conditions. Their work was concentrated, generally, in the parts of egg beds where eggs were most numerous, excavations being sometimes as numerous as 15 per square foot in small localized spots. . . . Predatism by western horned larks, and in the latter two instars, by hawks, was an undeterminable factor. These birds were very numerous and fed actively on nymphs on some areas, flocks of 50 hawks and 300 larks not being uncommon."

Later in the season he re-evaluated the effectiveness of horned larks in the destruction of *longipennis*. He said: "Horned larks have proven to be an important factor in reducing the egg-bed populations, especially in the heavier populated parts of the beds. Their excavations often have completely torn up the bare ground in small areas. They fed actively upon eggs in the spring of 1939 from the time the ground was thawed out until the hatch occurred in May. This fall they began their work shortly after August 1, and were still doing heavy damage to pods when observations were discontinued November 4."

Hildwein *(20*)* reported that in New Mexico in 1939: "Several instances occurred, particularly in Quay and Curry Counties, where eradication of hoppers was accomplished with a minimum amount of baiting which might indicate that natural enemies may have been a considerable factor. . . . Horned larks and lark buntings were present in large numbers during the early part of the 1939 campaign. . . . There was some evidence to indicate that they may have been a factor in reducing scattered populations of hoppers."

Spain *(72*)* noted the variability of bird and animal predators in 1939 when he recorded that: "There were egg beds in Texas with no predatory diggings and one egg bed in New Mexico with 35 percent of the pods consumed." He discovered that excavations of predators were a helpful guide in locating egg beds in the fall of 1938 and also in the following spring egg survey (figs. 24 and 25).

Birds, in addition to destroying eggs, prey upon nymphs. This is illustrated by Spain's further observations in 1939: "Horned larks and lark buntings fed actively on first- and second-instar *longipennis*, consuming an estimated 5 percent in Texas. The latter birds moved northward as hatching [of *D. longipennis*] progressed and many nested in northeastern New Mexico. After 85 to 95 percent of the grasshoppers had been controlled with bait in northeastern New Mexico, lark buntings and western horned

BN-1948

FIGURE 24.—Holes in the soil made by birds' digging *longipennis* eggs out of an egg bed. Guadalupe County, N. Mex.

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FIGURE 25.—Excavations made by small animals when they dug *longipennis* eggs out of an egg bed. Quay County, N. Mex.

larks destroyed up to 100 percent of the residual 'hopper populations."

Based upon the 1939 fall egg-bed survey, Scharff *(57*)* concluded that in the following spring the egg population had been reduced as much as 80 percent in one area in De Baca County,

N. Mex. He said: "The absence of any second-instar nymphs would indicate that growth conditions had not been favorable. Western horned larks, numbering perhaps 300 per acre, were seen on the beds." At the close of the season in 1940 he evaluated the effectiveness of control in Colorado counties as follows:

County	Acres baited	Percentage of control of *D. longipennis* by—		
		Birds	Weather	Bait
Cheyenne	1,740	5	39	55
Las Animas	1,250	5	89	5
Lincoln	50,910	5	4	90
Otero	7,640	5	74	20
Pueblo	2,290	5	84	10

On July 18, 1940, Scharff wrote of the situation in Colorado, thus: "In the Las Animas County infestation, birds, chiefly western horned larks, have destroyed as much as 50 percent of the eggs in the more concentrated parts of the egg beds. One egg bed in Otero County, covering about 2 acres, is populated by about 200 western horned larks and lark buntings which were seen to be feeding heavily on *longipennis* nymphs. Although the first hatch here was on May 6, and no baiting has been done on this bed, no second-instar nymphs could be found. It is possible that with the delayed hatch on this bed, the birds kept the older nymphs under control. Predatism on the whole, however, has not resulted in more than 25-percent egg and nymph reduction which still leaves the infestation severe."

As the result of extensive baiting operations in New Mexico in 1939, *longipennis* was of minor importance in 1940 except in small areas in Quay and De Baca Counties. Of these, Landrum *(83*)* said: "Periodical checks of these two areas were made during the winter months to determine if predators or parasites were causing reductions of the number of eggs present but it was found that no appreciable reduction had occurred."

Hawks congregating in conspicuous numbers where nymphs and adults of *longipennis* were numerous, were the subject of many reports by several supervisors in 1938–40. Local newspapers throughout the infested area also frequently publicized the phenomenon. Hawks fed greedily upon the grasshoppers, often to the exclusion of other food during the period when they could capture their prey with little effort. They were so engrossed in their orgy of feasting that many grasshopper workers observed them closely. When engorged they regurgitated on the ground and returned to their feeding or flew away to regurgitate and returned for more. When they captured adult grasshoppers they commonly tore off the wings and legs before swallowing the body.

Information on hawks as predators of grasshoppers is rather desultory in early literature. Samuel Aughey *(5, pp. [43]-[45])* found that the food of several species of hawks consisted, to considerable extent, of insects. According to Beal *(6, p. 345)*, "When

the Rocky Mountain Locust invaded the fertile plains of the Mississippi Valley [in the 1870's], Professor Aughey found that it was preyed upon by every species of land bird, and even by some water fowl. Birds that normally fed upon other food, attracted by the unusual abundance of these insects, ate them freely and continuously while they lasted."

Further, concerning Aughey's findings, McAtee *(59, p. 419)* summarized them thus: "Tempted by the abundance and accessibility of these insects, birds of every kind flocked to the feast. Land birds and water birds, tree frequenters and plains dwellers, whether normally fish, flesh, seed, or fruit eaters—all, from the diminutive humming bird to the largest hawks, came to feed upon grasshoppers."

Concentrations of hawks feeding upon grasshoppers have been briefly reported in earlier literature by several observers. Fisher *(36, p. 12)* said:

> Swainson's Hawk . . . is of great service, warring upon creatures which do injury to crops. . . . Grasshoppers and crickets are particularly sought after, and on the foothills and plains of the West Swainson's Hawks congregate in large flocks wherever these insects are abundant. . . .

Quoting T. S. Palmer, a correspondent of Berkeley, Calif., Fisher wrote of the numbers of grasshoppers contained in two specimens of Swainson's hawk *(p. 76)*:

> Upon dissection the gizzard [of one specimen] was found to be tightly packed with grasshoppers, and the bird had no doubt gorged herself, for when I approached the tree in which she was sitting she made no attempt to fly even when I was almost under her. My second specimen [was] a typical male . . . Both the gizzard and oesophagus were filled with grasshoppers . . . I found 110 pairs of the large hind legs, while an assistant counted 133 heads. It is safe to say that this hawk had captured 125 grasshoppers before 9 A. M.

Fisher reported also *(36, p. 116)* on the sparrow hawk:

> The sparrow hawk is almost exclusively insectivorous except when insect food is difficult to obtain. In localities where grasshoppers and crickets are abundant these hawks congregate, often in moderate-sized flocks, and gorge themselves continuously. Rarely do they touch any other form of food until, either by the advancing season or other natural causes, the grasshopper crop is so lessened that their hunger can not be appeased without undue exertion. . . .
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> * * * * * * * * * * * *
>
> H. W. Henshaw [said:] "where [grasshoppers] are abundant I have never seen [sparrow hawks] have recourse to any other kind of food."

Fisher said that a dozen or more stomachs of sparrow hawks were collected in Gallatin County, Mont., in late August and early September 1888. These stomachs were dissected by the Division of Ornithology and Mammalogy and found to contain little else than grasshoppers and crickets.

Fisher also gave facts concerning the extent to which a number of owls fed upon insects. Among these were the screech owl and the burrowing owl which later were identified as grasshopper predators of *longipennis*. He said *(36, pp. 165, 191-192)*:

> No owl except the burrowing owl is so destructive to noxious insects as [the Screech Owl], it devouring with relish grasshoppers, crickets, and a number of night-flying beetles. . . . Prof. Samuel Aughey . . . states: "It is largely an insect-eating bird." Dr. B. H. Warren says: "During the summer months and at other times when insect life is abundant the screech owls subsist mainly on an insect diet." . . .
>
> In the summer and fall, when grasshoppers and crickets are exceedingly abundant on the western plains, the burrowing owl feeds almost exclusively on such food. . . . this little owl will chase and devour grasshoppers until its stomach is distended to the utmost. In all the stomachs the writer has examined . . . the remains of grasshoppers or crickets were always found.

McAtee wrote *(58, p. 411)*:

> The general utility of birds in checking the increase of injurious animals and plants is well understood. It must be admitted, however, that while birds constantly exert a repressive influence on the numbers of the organisms they prey upon and even exterminate certain pests locally, they are not numerous enough to cope successfully with widespread invasions.
>
> Birds are prone to feed upon things which are abundant and easily accessible. For instance, in elderberry season a very large number of birds take elderberries; if mayflies swarm in a locality, practically all of the birds there devour mayflies. Thus, under unusual conditions, such as attend outbreaks of insect or other pests, birds very naturally turn their attention to the plentiful and easily obtained food supply, and the attack on a particular pest often is intensified also by the flocking in of birds from surrounding areas.

The first published record found that listed hawks as predators of *longipennis* was that of Smith *(87)* in which he included the desert sparrow hawk among the more important bird enemies observed to feed upon grasshoppers during the outbreak in Roosevelt County, N. Mex., in 1913.

Speaking of the area infested by *longipennis* in Washington County, Colo., in the summer of 1938 Spain *(64*)* said: "regurgitated grasshopper pellets of hawks can be found over a great percent of this marked area."

In Colfax County, N. Mex., in 1938, Resley *(64*)* found that: "Flights of hawks invariably follow the egg beds [where grasshoppers congregated for egg-laying] but the ranchers reported they had seen more this year."

Concerning the help of natural enemies in Colorado in 1939, Kropf *(29*)* said: "In *D. longipennis* areas our greatest aid was that of various species of hawks. The work of these birds started near the Cudhay Ranch, Crowley County, and along Adobe Creek, Kiowa County, when *D. longipennis* were in the third and fourth instar. During adult poisoning in Otero and Pueblo Counties a flock of 1,500 to 2,000 hawks had much to do with control on egg beds."

"The short laying period of *D. longipennis* grasshoppers can be directly credited to hawks in many areas," said Davis and Mickle *(3*)* of Colorado in 1939. "Bands of hawks ranging from a few dozen to upwards of 2,500 were observed in every area

where large concentrations of laying adults occurred. Within a few days after the arrival of the hawks there was scarcely a 'hopper left." Mickle *(42*)* reported that when scouting by airplane in the fall of 1939 and in the spring of 1940 observers' attention was directed to egg-laying beds by the presence of large numbers of hawks in localities where grasshoppers were congregated.

Scharff *(72*)* reported in 1939:

> A band of more than 5,000 hawks . . . are feeding on 'hoppers in Lincoln County. In less than 20 minutes during the middle of the day, August 25, 3 of them were seen to catch 34, 20, and 14 *longipennis*, respectively. . . . Within weeks after the *longipennis* adults had begun to lay, hawks, chiefly Swainson's . . . and rough-legged, began to gather in the vicinity of the banded 'hoppers. By the last week in August, an estimated 8,000 hawks had congregated and were feeding almost exclusively on 'hoppers in the largest band in Lincoln County, Colorado. Somewhat lesser numbers of hawks were found feeding on other infestations. Information indicates that this occurrence has been a general happening in past years.
>
> In Lincoln County infestations, when poisoning operations were discontinued on August 31, *longipennis* averaged 10 per square yard over about 300 acres. On September 3 about 1 per square yard could be found, and on September 8 only one was visible occasionally. Doubtless some died from poison and parasitism. By this time hawks had dispersed to about normal population. In the vicinity of the infestation are a few small groves of trees in which the hawks roosted at night. Under these trees and covering at least 15 acres in numbers averaging 15 per square yard, were the typical pellets of indigestible matter, regurgitated by the hawks. A careful examination revealed them to be composed of more than 99 percent *longipennis*. Each pellet contained the remains of from 14 to 19 'hoppers.

In the same report Spain and Scharff *(72*)* said that after baiting was discontinued in Lincoln County, Colo., in 1939: "A residual population of 10 *longipennis* per square yard over 300 acres was annihilated by these hawks [not before some eggs were laid] with the help of Sarcophagids and other natural factors."

Kropf's observations *(29*)* were that the large bunches of hawks were composed principally of Swainson's hawk, the American rough-legged hawk, and the ferruginous rough-legged hawk. In one case these roosted at night in a grove of cottonwood trees. He examined a number of regurgitated pellets collected on the ground beneath the trees and found they contained an average of 35 grasshopper headplates each. The red-tailed hawk tended to range more to itself, selecting isolated trees away from those where the massed bunches perched. He observed many sparrow hawks feeding on *longipennis* but these usually did not mingle with the massed bunches. In 1 hollow tree he found 7 sparrow hawk nests and observed that the parent birds ranged long distances to procure the grasshoppers they carried back to their young. He recorded burrowing owls as feeding avidly upon the grasshoppers, and one screech owl, in an isolated tree, that disgorged pellets that were composed mainly of grasshopper remains.

On June 23, 1940, Scharff *(57*)* reported: "During the past week in Lincoln County, the large sailing hawks have been noticed congregating slightly on the very small remnants of baited

bands of sixth-instar and adult *D. longipennis.*" On July 7, in the same county he said: "hawks have been seen congregating on concentrations of emerging adults, and it is expected that any small swarms . . . which have escaped baiting, will be reduced to economic unimportance by natural factors before oviposition begins. . . ."

Although field workers of the Federal Fish and Wildlife Service have not recorded concentrations of large numbers of hawks in the High Plains area, E. R. Kalmbach, biologist in the Service, believes, from the distribution pattern and migration habits of several species of hawks, that concentrations are not improbable. Robert J. Niedrach, ornithologist in the Denver Museum of Natural History, on one occasion in 1939 saw hawks feeding on the lubber grasshopper on the Highland ranch a few miles south of Denver, Colo. In that instance he estimated there were about 1,000 hawks in the congregation.

Observance of a phenomenon so unusual as the immense concentrations of hawks in the 1933–40 outbreak of *longipennis* is largely a matter of fortuitous circumstance—workers being in the right place at the right time, incidental to their regular duties.

Supervisors working on grasshopper survey and control during the period under discussion had the rare opportunity of making on-the-ground observations. In their weekly and special reports in 1939 and 1940 huge concentrations of hawks feeding upon late instar nymphs and adult grasshoppers were a commonplace subject. Here, a quotation from Kalmbach *(51, p. 731)* is particularly apt. "As one delves through the literature on the subject, he is impressed also by the fact that recognition of insect destruction by birds has come more frequently from the entomologists directly concerned with matters of insect suppression than from the ornithologists whose interest in the welfare of birds might at times bias deductions. In fact, the entomologists, confronted as they are with the problem of seeking every possible means toward achieving pest insect control, have ample reason for recognizing biological help from whatever source it may stem."

Information obtained by examination of stomach contents of species of hawks and owls found in the *longipennis* habitat is contained in tables 17 and 18.

Assembly of hawks was a process that gradually increased in momentum. Those within infested areas were first attracted locally to the concentrated bands of grasshoppers and served as decoys for migrating birds that continually swelled the hawk bands as long as the food supply was abundant and easily obtained. When the grasshoppers became scarce, hawks rapidly returned to about normal distribution. Kropf *(29*)* believes that after hawks had come together to form flocks, they tended to move on in flocks when the food that had originally attracted them became scarce. On several occasions he saw such flocks approach from a distance and alight to feed upon grasshoppers that were thickly congregated.

TABLE 17.—*Insects found in the stomachs of hawks and owls*[1]

Kind of hawk	Number of stomachs examined	Stomachs containing food				
		Total	Stomachs containing insects, including grasshoppers		Stomachs containing grasshoppers	
			Number	Percent of total	Number	Percent of total
Red-tailed	562	477	45	9.4	29	6.1
Swainson's	18	15	8	53.3	6	40.0
Rough-legged	49	45	1	2.3	0	0
Sparrow	320	295	213	72.2	107	36.3
Screech owl	254	218	86	39.4	23	10.6
Burrowing owl	32	31	30	96.8	16	51.6

[1] Adapted from Fisher (*36*).

TABLE 18.—*Range of hawks that normally occur in the* longipennis *habitat and animal contents of stomachs and crops* [1]

Kind of hawk	Number examined	Range of hawk		Animal contents of stomachs and crops		
		Breeding	Winter	Animals	Insects	
				Number	*Number*	*Percent*
Red-tailed	1,013	In habitat	In habitat	1,304	92	7.1
Swainson's	44	In habitat	----------	49	31	63.3
American rough-legged.	202	----------	In habitat	261	19	7.3
Ferruginous rough-leg.	24	In habitat	In habitat	27	2	7.4
Sparrow	427	In habitat[2]	In habitat	528	269	50.9

[1] Adapted from May (*61*).
[2] Desert sparrow hawk in southern part only.

CONTROL

1913

Control of *longipennis* was not attempted before 1913. That year, poisoned bait, tested for the first time in Roosevelt County, N. Mex., proved its effectiveness; Smith *(87, p. 11)* stated that "tremendous numbers of the grasshoppers were exterminated" by the use of poisoned bait composed of: Wheat bran, 25 pounds; paris green, 1 pound; molasses, 2 quarts; the juice and finely ground rind and pulp of 3 oranges or lemons; and water to moisten. He said, "As many as 75 dead grasshoppers per square foot were frequently found, several days after the application, over large areas." He found no lessening in the efficiency of bait from which citrus fruits had been omitted.

1921

The first organized campaign directed toward the control of the species by use of poisoned bait was in Crowley, Lincoln, and Pueblo Counties, Colo., in 1921. Of that case Corkins *(28, p. 38)* says: "This species was very easily controlled with poison bran mash. The 'hoppers took the mash more readily than any of our common epidemic species. No salt was included in the formula. At first, lemons were used and later amyl acetate, apparently with about equal results." He briefly described the organizational plan and procedure followed in the control campaign. He stated that, except for bait ingredients and transportation, which together cost $5,967.26, all costs were met through voluntary contributions of services. The source of money expended for bait and transportation was not indicated.

The amount of bait used indicates that bait was applied to approximately 15,000 acres. The materials incorporated into bait were:

Bran	75 tons
Molasses	3,000 gallons
White arsenic and paris green	7,500 pounds
Lemons and oranges	2,000 dozen
Amyl acetate	15 gallons

Projected into the cash equivalent from cost figures derived in later years, the total cost of the 1921 control program was about as follows:

Bait materials and motor transport	$5,967
Bait mixing	150
Bait spreading	554
Total	6,671

1934

Control of the High Plains grasshopper in 1921 was financed by voluntary contributions in the form of labor, transportation,

and so forth, with possibly some assistance from State or county sources. In the 1934 outbreak the Federal Government became a participating cooperator by sharing some of the expenses of the control campaign. This was possible when Congress appropriated funds enabling the United States Department of Agriculture to cooperate in grasshopper control with those States in which the problem of control was serious. Administration of the Federal portion of the cooperative endeavor—provisions of bait materials and limited supervision—was placed in the Bureau of Entomology and Plant Quarantine. Colorado applied for and used Federal bait materials, as authorized by legislation, to combat the 1934 outbreak in Lincoln County.

At the close of control operations, McCampbell *(33*)* estimated that ranchers had killed from 75 to 80 percent of the grasshoppers, thus controlling them on 500 of the 700 square miles they had infested when the campaign started. He said further:

> One hundred thirty tons of dry bran mixed with poison were supplied by the Federal Government and used in killing the pest [in Lincoln County]. . . . With the experiences of the 1921 outbreak fresh in the minds of her farmers, Lincoln County started fighting hoppers shortly after the eggs had hatched in the spring. Neglecting farming operations and devoting full time to fighting this pest, the citizens of this area have performed a public service that demands the gratitude of all surrounding farm areas. Citizens of many towns and the surrounding districts have contributed both time and money to this campaign. . . . Not all of the 'hoppers were killed before they developed wings, due to the fact that areas were infested which were so thinly settled, and no one felt the responsibility of poisoning these areas until the 'hoppers close to home were eradicated.

Deduced from the amount of materials used, about 26,000 acres were baited in the 1934 campaign. The estimated cost of the control campaign was as follows:

Bureau of Entomology and Plant Quarantine:		
Bait materials	$2,964	
Freight	570	$3,534
Colorado Extension Service		1,000
Ranchers:		
Bait mixing	260	
Bait spreading	960	1,220
Total		5,754

1936

Large numbers of adult grasshoppers flew into eastern Colorado in 1936. They alighted on land not known to have been infested previously that year. Ranchers generally thought that the grasshoppers had flown in from Mexico or other areas south of Colorado. It is certain, however, that at least part of the flight of grasshoppers originated from local sources, for the 1935 fall survey had revealed that the species was present in Cheyenne, Prowers, and Weld Counties, Colo., and predominant in Baca and Kiowa Counties *(59*)*.

Of that infestation McCampbell *(35*)* said: "During August a flight of *Dissosteira longipennis* occurred in southeastern Colorado

counties. The principal damage resulting from this flight occurred in Lincoln, Cheyenne, Kiowa, Prowers, Baca, and Las Animas Counties. . . . The Lincoln County agent estimated that 400 square miles were infested and 32,000 acres of valuable pasture defoliated. This flight came at a time when it seemed almost too late to organize a campaign sufficiently large to take care of the situation. Some poisoning was done with good results. However, for the most part 'hoppers laid large numbers of eggs in the most seriously infested counties and an unusually large epidemic is expected next season. . . . Estimates for this area were from 10 percent to 20 percent of the winter range destroyed."

The first survey directed specifically toward determining the extent and severity of an infestation of *longipennis* was conducted cooperatively by the State of Colorado and the Bureau of Entomology and Plant Quarantine in the fall of 1936 *(35*, 61*)*. It revealed that the infestation involved an area from the southern Colorado boundary northward for 125 miles and from the eastern boundary westward for 75 miles. The entire area was not surveyed intensively, but about 2,000,000 acres of rangeland were known to harbor scattered egg beds of unknown number and size. Survey findings served to warn ranchers and other cooperators of the difficult control problem ahead. Plans based upon the results of the egg survey were prepared by the cooperators for control of *longipennis* in Colorado in 1937; these called for spreading 898 tons of bait on 184,100 acres of land *(61*)* or approximately 9.2 percent of the area known to be infested.

Information on the importance and control of *longipennis* in New Mexico in 1936 is indefinite. Hollinger *(24*)* said: "In Union County, in recent weeks, there have been several small outbreaks of migratory grasshoppers that have come into small bands and are very destructive. With some Government supplies of bran and poison immediately available, the outbreaks seem to have been well controlled."

Some control of the species was undertaken in Oklahoma in 1936, but the extent and cost is unknown. In his annual report, the State leader said *(74*)*: "The . . . long-winged grasshopper, *Dissosteira longipennis*, was quite numerous in Cimarron County during August and was reported damaging rangeland to such an extent that poisoning was necessary. . . . In Texas County grasshoppers did not make their appearance until late in the summer . . . at which time they became very numerous, flying in from the rangelands of Kansas, New Mexico, and Colorado. They became so numerous in October that it was necessary to poison them. . . . The Soil Conservation Service furnished trucks to haul sawdust from Springer, N. Mex., which cut the cost to the farmers considerably. All of the mixing was done at Guymon. . . ."

1937

The survey conducted in 20 western and midwestern States in the fall of 1936 revealed that the grasshopper population in 1937 would be measurably greater than it had been in 1935 and 1936. Alarmed at the prospect, entomologists from the more heavily

infested States met in Omaha, Nebr., on December 4 and 5, to consider means for averting crop destruction in 1937. Resolutions prepared by a committee of seven, and unanimously approved by the delegates in attendance, emphasized that "emergency Federal appropriations for aid in control of regional insect outbreaks usually become available too late seasonally to be used with maximum efficiency and economy; therefore *Resolved,* that this conference urges that the 1937 Congress establish, and subsequent Congresses maintain, a fund of five million ($5,000,000) dollars to be replenished to the original amount at the beginning of each fiscal year whenever such replenishment is necessary, to be available to and administered by the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. . . ." *(80*).*

The intent of the resolution was to encourage legislation that would assure purchase and delivery of control materials so they would be on hand in field locations in time to obtain the most effective and economical results and to guard against exhaustion of funds at the end of June, when grasshoppers might be at their peak in abundance and destructiveness.

A Joint Resolution, passed by Congress and approved by the President, is quoted in part as follows: "That for carrying out the purposes of and for expenditures authorized under the public resolution entitled 'Joint Resolution making funds available for the control of incipient or emergency outbreaks of insect pests or plant diseases, including grasshoppers, Mormon crickets, and chinch bugs, approved April 6, 1937, there is hereby appropriated, out of any money in the Treasury not otherwise appropriated, the sum of $1,000,000, to remain available until June 30, 1938: Provided, That, in the discretion of the Secretary of Agriculture, no part of this appropriation shall be expended . . . in any State until such State has provided the organization or materials and supplies necessary for cooperation. . . ."

J. R. Parker was in field charge of grasshopper control for the Bureau of Entomology and Plant Quarantine in 1937. In his annual report he said *(47*)*:

> As a result of this action [of the Omaha conference] and the cooperation of the Secretary of Agriculture and the Chief of the Bureau of Entomology and Plant Quarantine, a Joint Resolution of the House and Senate . . . embodied the main objectives of the Omaha Conference with the exception that the original amount asked for any one fiscal year, $5,000,000, was reduced by Congress to $2,000,000. Following the passage and approval of the authorizing resolutions an appropriation of $1,000,000 was made. This became available on April 29, when the President signed the bill. On July 17, another appropriation of $1,000,000 was made, to remain available until June 30, 1938. Of these two appropriations, made for the general purpose of emergency insect control, $995,000 of the first and $430,000 of the second, or a total of $1,425,000 was allocated by the Secretary for grasshopper control.

The Chief of the Bureau, in his instructions to cooperating States, said *(78*)*: "In view of the fact that the President of the United States submitted to Congress an estimate of $2 million for

grasshopper control, in which the emergency created by this insect was recognized, and in view of the extent and severity of the impending outbreak in many States, all of the funds made available under the above legislation [of April 29] are being allocated for grasshopper control. This appropriation provides only about half the amount estimated as required by the fall survey. . . ."

Colorado

Preparatory to the 1937 control campaign, the Colorado Extension entomologist *(38*)* conducted numerous educational and organizational meetings in all counties where infestations were known to exist. County agricultural agents then held similar meetings in their respective counties. County commissioners, assembled in their annual and regional meetings, were informed of the serious control problem ahead and acquainted with the plans for coping with it. All agencies interested in the State's agriculture were advised of the results of the 1936 survey and of plans for the control campaign.

The plan of work in Colorado was that control would be conducted voluntarily by cooperating counties and ranchers with bait materials provided by the Bureau. The Colorado Agricultural Extension Service directed the control campaign, areawide, through the Extension entomologist, and countywide through the county agricultural agents. Bait-mixing stations were established in each county and the control organization was in good working order well before the first *longipennis* nymphs appeared.

Tests for bait formulas, made before control operations were begun, indicated that a bait composed of sawdust, liquid sodium arsenite, and water, and one in which bran was used in the proportion of 1 part to 7 parts sawdust, were both effective in killing nymphs of *longipennis*. Subsequently it was determined that in instances where control with these formulas was unsatisfactory, effective kills resulted when the proportion of bran was increased. Most of the bait used was prepared according to the standard formula of:

Millrun bran	100 pounds
Sawdust	3 times the volume of bran
Liquid sodium arsenite—(4-lb. material)	2 gallons

In the *longipennis* area bait was scattered on all land where infestations warranted its use, without regard to ownership. In a few cases pest districts were formed or the authority of those in existence exercised to insure treatment of an infested area. For the most part all members of a community cooperated to spread bait simultaneously. Nonresident land posed a problem solved only by pest-district action or by members of a community trespassing on nonresident land that needed treatment in order to protect the work of resident cooperators. Trailer-type mechanical bait spreaders were used to spread most of the bait.

Temporary headquarters for the Extension entomologist were established in Colorado Springs; from there he could better direct control operations in the counties infested by *longipennis*. The

Colorado Springs News on July 2, under the heading "Greatest Hopper War is Directed from Colorado Springs" published a news story describing the outbreak and steps taken to combat it. The article said in part:

> Well-organized, vigorously prosecuted, and ably directed, an effective campaign is being relentlessly waged from Colorado Springs headquarters this week against the worst grasshopper infestation in Colorado history—great hordes of migratory insects that are moving along in destructive battalions of millions, even billions, in a hard-hit area of 4,000 square miles in nine eastern and southeastern counties: Lincoln, one of the most seriously infested, Cheyenne, Kiowa, Kit Carson, Prowers, Baca, Bent, Las Animas, and Otero. Efficient director of the campaign against the insect scourge is Sam C. McCampbell, extension entomologist with Colorado State College, who has opened headquarters in the local soil conservation service offices. There is a hard fight ahead for some time, but the campaign already is showing good results.
>
> The campaign was gotten under way with celerity, poison bait supplies being rushed to mixing and distributing plants in every county. No time can be lost for the 'hoppers, of a migratory type, soon will be able to fly to other fields unless halted. Meantime, to the east and southeast, tremendous damage has been done to crops and pasture in what F. A. Anderson, director of Extension for Colorado State College, describes as the worst grasshopper situation in the State's history. Governor Teller Ammons, who has made personal surveys of the infested areas, reports conditions worse than described. . . .
>
> The huge size of the economic unit in eastern Colorado presents one of the greatest obstacles to perfect 'hopper control. The country is principally a stock-raising country, and many operators own or control thousands of acres of land. The size of these holdings, plus economic conditions, makes it almost impossible for the average stockman to secure help to eradicate all the hoppers on his own area. These factors make it almost essential that the county, state and federal governments unite with the farmer in a concentrated effort to save his vegetation. Federal, State and county agencies are assisting throughout the infested areas. . . .

The 1937 appropriation was allocated for the provision of bait to the cooperating States in proportion to the severity of their control problems, with the realization that adequate grasshopper control could be accomplished only if additional funds were provided. The amount of bait allotted to Colorado was insufficient for early season control of the *longipennis* populations. Although the appropriation was passed on April 29 time was required to acquire a staff to administer the control project and to negotiate contracts for the purchase of supplies. The first allotment for bait materials to Colorado was made May 12 *(47*)* after which the materials had to be purchased and delivered. The Extension entomologist said *(38*)*: "The campaign would have been at least 25 percent more effective if bait could have been on hand . . . May 15, 1937, or earlier."

When completion of the control program was jeopardized by a shortage of bait materials, the editor of the Eastern Colorado Plainsman and Range Ledger addressed a telegram to the President of the United States and received the following reply, published in the July 16, 1937, issue of the paper:

A letter from Agricultural Head

Department of Agriculture
Washington, D. C.
July 9, 1937

Dear Mr. Missemer:

This will acknowledge your telegram of June 29 addressed to the President, regarding grasshopper control and which was referred to this department for attention.

The funds provided to the Department to cooperate with states in the control of grasshoppers were used for the purchase of bait materials and transporting them to designated distribution centers in the states. The State Grasshopper Control Committee of Colorado has been advised of the bait materials that could be allotted to that state with the funds provided. The amount appropriated has been expended and in the absence of funds it will be impossible for the Department to extend further cooperation to states in control of grasshoppers.

The Department, with the approval of the President, and the Bureau of the Budget, requested an appropriation of $2 million to cooperate with states in grasshopper control. This amount was based on careful surveys made by the Bureau of Entomology and Plant Quarantine in cooperation with state officials, and so far this season grasshoppers have developed in areas substantially as was predicted by these surveys. The appropriation made by Congress was in the sum of $1 million and this constitutes the limit of which may be expended by the Department.

The Department is familiar with the grasshopper situation in the various states and, as indicated above, has done all they can toward securing the necessary funds with which to cooperate with states in grasshopper control.

In some few instances men from Emergency Conservation Corps camps have been authorized to render aid in distributing materials for combatting grasshoppers. The management of these camps is not under the direction of the Department and appropriate reference will be made regarding the request that the camps in this locality be authorized to conduct the distribution of grasshopper bait as one of their objectives.

Sincerely,

Paul H. Appleby
Assistant to the Secretary.

The last allotment of bait materials to Colorado purchased from the April 6 appropriation was on July 2 *(47*)*. An accelerating control demand in the face of inadequate bait materials impelled the Governor to assess the situation and take action. According to the Eastern Colorado Plainsman and Range Ledger, July 2, he made a trip to Lincoln County. This trip followed advice . . . that only a 2-day supply of bait remained in the 9 counties where control of *longipennis* was underway. In addition to ordering the National Guard to mobilize and throw its manpower and equipment into the control campaign, according to the Rocky Mountain News, July 1, he "issued an executive order declaring a state of emergency exists . . . and said 'I don't believe we can let up now as crop prospects are the best in several years.' "

State, county, and individual funds were expended to keep bait materials rolling to mixing stations until the additional funds

were made available by Congress, July 17. The first allotment of bait materials purchased out of new Federal funds was July 21 *(47*)*.

It was impossible to plan and carry out the most effective coordinated control campaign, for there was no assurance that funds would be available with which to finance the work known to be needed. The State leader had no knowledge of the amount of Federal funds that would be allotted, or of whether or in what amount State assistance could be depended upon. He had to revise plans from week to week in accordance with the current infestation picture and the means at his disposal for combating it. An admirable example of cooperation developed from the necessity of obtaining assistance from every source available.

The Press, realizing the economic impact of grasshopper devastation upon all types of business, devoted thousands of inches of space to keeping farmers and cooperators abreast of developments in the infestation, informing them of assistance as it became available and of the results of control.

Two such items are briefed below.

The Colorado Springs News on June 18 reported that stockmen in nine southern Colorado counties were fighting the greatest outbreak in history of the long-winged migratory grasshopper of the plains. Numerous bands of millions of young 'hoppers were on the march, bands covering from a few acres to more than 500. County agents had organized ranchers and farmers for the fight. The Soil Conservation Service was trucking poison to community distributing plants and building bait spreaders. Fifty bait spreaders were already in use. It was hoped that the grasshoppers could be controlled before they developed wings early in July.

On July 2, the Rocky Mountain News reported that the WPA administrator for Colorado had been authorized to employ labor, beginning July 1, on grasshopper-control projects. WPA officials in Washington had promised a $200,000 allotment of WPA funds to be used for this purpose in Colorado.

McCampbell *(62*)* estimated that 3,432,000 acres of range had been damaged by *longipennis* during 1937. Although magnificent cooperation was obtained, results were less effective than they should have been for the money expended and the equipment and manpower employed. Much of the assistance became available only after it was conspicuously apparent that the range area was faced with calamity. Most of the workers and their supervisors assigned by cooperating agencies were untrained and inexperienced in grasshopper control. The herculean control campaign was successful in stopping devastation by *longipennis* in the areas most heavily infested, but did not reduce the infestation to be fought in 1938. McCampbell recognized this when he said *(39*)*: "The grasshopper campaign of 1937 in the migratory areas of southeastern Colorado and adjacent States was not effective in exterminating the infestation. Thousands of dollars were saved by control operations. However, sufficient 'hoppers flew into new areas to cause an infestation larger than that for 1937. Migratory 'hoppers have laid eggs in Adams, Otero, Elbert, El Paso, Lincoln, Pueblo, Huerfano, Crowley, Kiowa, Prowers, Bent, Baca, Las Animas, Fremont, Custer, and possibly other adjoining counties."

After the survey was completed in 1937, McCampbell stated that instead of 9 counties being infested with *longipennis*, the number known in the spring, 12 were so heavily infested that they should be considered in control plans for 1938.

Following is an estimate of expenditures for the control program in Colorado in 1937:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1] [2]	
Materials (cost and freight):	
Bran, 1,418 tons at $23.51 per ton	33,337
Sodium arsenite, 56,740 gal. at $0.40 per gal.	22,696
Supervision (salaries, travel, expense)	2,000
Total	58,033
Other: [1] [2]	
Soil Conservation Service and Forest Service	25,000
Civilian Conservation Corps	22,106
Works Progress Administration	23,631
National Park Service	3,000
Total	73,737
Total expenditures by Federal Government	131,770
State Government: [2] [3]	
Extension Service (supervision, travel, clerical)	12,298
National Guard (trucks, transportation, equipment, labor)	99,884
Highway Department (trucks, power shovel, personnel)	25,000
Certificates of indebtedness	25,000
Total expenditures by State Government	162,182
County Governments (mixing-station equipment, rental, supplies, labor) [2]	10,000
Individuals (spreading of 5,674 tons bait by ranchers, at $7.39 per ton) [1] [2]	41,931
Total expenditures from all sources	345,883

[1] Based on data in Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(47*)*.
[2] Based on data in Annual Grasshopper Survey Report, Bureau of Entomology and Plant Quarantine *(61*)*
[3] Based on data in Annual Report, Colorado State Leader of Grasshopper Control *(38*)*.

New Mexico

Control of *longipennis* in New Mexico in 1937 was directed statewide by the New Mexico State College, and locally by the county agents. Educational and organizational meetings and demonstrations were conducted before operations began. Bait materials were provided mainly by the Bureau. Bait mixing was done by counties with labor hired from funds allotted by the Works Progress Administration. The Soil Conservation Service, the National Guard, and the State Highway Department furnished trucks and men to transport bait materials to mixing stations and to haul mixed bait to the infested areas. The State, counties, and individuals contributed limited funds for the conduct of the cooperative campaign.

The Soil Conservation Service provided 5 trucks and 11 men for transporting bait materials from railroad shipping points to

mixing stations. The Highway Department trucked sawdust from the mills to mixing stations. Four mixing stations were operated in Union County by Works Progress Administration crews which mixed bait day and night for several weeks. The bait was hauled to infested areas by 14 trucks and 60 men furnished by the National Guard. The Santa Fe and Burlington railroads cooperated by controlling the grasshoppers on their rights-of-way in infested areas. Baiting started June 10 and continued until the first fall frost. Control was conducted on an organized, communitywide basis in which ranchers and farmers spread all of the bait. A few mechanical spreaders were used but most of the bait was scattered by hand.

The standard bait formula was used after tests indicated bait was not improved in effectiveness when amyl acetate or molasses was added *(2*)*.

Newspaper interest and publicity aided materially in carrying out the 1937 control campaign in New Mexico. Two typical news items are briefed below:

On May 12 the Clayton News reported that a survey had been made of grasshopper eggs in the ground in Union County, that the rains and warm days were hatching the eggs by the thousands, and that the grasshoppers would be a serious menace by summer unless they were controlled. The item urged readers to attend a local meeting on grasshopper control and to cooperate in the plan to spread poison bait to kill the grasshoppers and thereby save the crops.

On July 4 the Denver Post reported that all available forces were being recruited in northeastern New Mexico to combat a grasshopper invasion that was threatening the first grass and crop prospects the section had had in 5 years. Gov. Clyde Tingley, according to the report, had authorized the purchase of $15,000 worth of poison-bait materials, had ordered out National Guard trucks with 60 men to man them, had ordered State highway trucks to haul sawdust to be used in the bait, had secured Soil Conservation Service trucks to help spread the poison, had arranged for a crew of WPA workers to mix the poison, and had organized local forces to help in control.

At the close of the campaign the State leader said *(2*)*: "The most destructive outbreak occurred in Union County where *longipennis* destroyed some 350,000 acres of range grass. The outbreak was difficult to handle due to the infestations being scattered over an area 30 by 50 miles. . . . However the infestation was definitely checked and the value of the campaign can be better expressed in terms of what was saved than in terms of the area baited." He reported that 718 tons of bait were spread on 339,000 acres of range in Union County. He estimated that range losses amounted to $172,215 and that savings resulting from range baiting were $459,000.

Aside from expenditures definitely credited to Union County 90 percent of the State expenditure was included in the following itemization of expenditures because 93 percent of the range acres baited was for control of *longipennis*.

Factors that worked against conducting the most efficient and effective control campaign in New Mexico were the same as those enumerated for Colorado, notably the lateness and insufficiency of Federal funds and the change of plans from day to day to accommodate them to the means available for carrying them out. Cooperation of local and State agencies was magnificent but it became fully operative only after the early season was past when control would have been the most effective and economical. Personnel provided by cooperating agencies was mainly untrained and inexperienced in grasshopper control.

Following is an estimate of expenditures for the control program in New Mexico in 1937:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1]	
Materials (cost and freight):	
Bran, 179 tons at $23.51 per ton	4,208
Sodium arsenite, 7,180 gal. at $0.40 per gal.	2,872
Supervision (salaries, travel, expense)	2,700
Total	9,780
Other: [2]	
Soil Conservation Service	1,500
Works Progress Administration	2,740
Total	4,240
Total expenditures by Federal Government	14,020
State Government: [2] [3]	
Extension Service (supervision, travel, clerical)	2,500
Allotment from wind erosion funds	4,328
State Highway Department	2,250
National Guard	4,050
Total expenditures by State Government	13,128
County Governments (cash) [2]	813
Individuals (Spreading 718 tons bait by ranchers, at $7.00 per ton) [1] [2]	5,026
Total expenditures from all sources	32,987

[1] Based on data in Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(47*)*.
[2] Based on data in Annual Grasshopper Survey Report, Bureau of Entomology and Plant Quarantine *(61*)*.
[3] Based on data in Annual Report, New Mexico State Leader of Grasshopper Control *(2*)*.

Oklahoma

The High Plains grasshopper was present and injurious to range in Cimarron County, Okla., but the meager information available precludes a conclusion concerning its economic importance or the amount of control occasioned by it.

W. E. Baker, agricultural agent of Cimarron County, in the Boise City News, May 27, 1937, said:

> Investigation the past 2 weeks and the reports of farmers and ranchmen throughout the county have indicated that young grasshoppers have been hatching out by the many millions. Examinations

> of the various localities show that there are now enough young grasshoppers in the county to destroy all range pasture and all row crops as fast as they come up. . . . As the grasshopper which infested this territory last year and is prevalent at the present time is what is known as the long-winged grasshopper and readily takes to flight, we were unable last year to have the success in poisoning the mature grasshopper which we desired. However, these young hoppers do not have wings and will not move for some time. . . . We are making arrangements to begin mixing the poison today.

It was barely mentioned in 1937 in the State leaders' annual report. He said *(11*)* that in the Panhandle counties it was dominant and that "there was considerable movement among the *longipennis* grasshoppers . . . On July 15 a flight of grasshoppers was reported in Cimarron County—but they did not stay long and damage was very slight. They were apparently moving in from New Mexico and later moved on toward the northwest."

1938

The grasshopper problem had become so acute that in 1938 the Bureau of Entomology and Plant Quarantine decided to create a specific organization for discharging Federal responsibilities in cooperating with States in grasshopper control. Federal responsibility for control operations was placed in the Division of Domestic Plant Quarantines, which created the Grasshopper Control Project, with W. E. Dove in charge.

Describing the control project, Gaddis *(12*)* said:

> The details as to administration and direction of cooperative programs were, with the approval of the Secretary of Agriculture, placed with the Bureau of Entomology and Plant Quarantine under a division concerned with the conduct of operations to control or eradicate certain insect pests or plant diseases. Field headquarters were established at Minneapolis, Minnesota, in February 1938 and the individuals selected to have charge of the work were trained employees familiar with government procedure and practices. . . . The Chief of the Bureau was directed to advise States in which outbreaks of grasshoppers were anticipated of the basis for cooperation and the type of organization that they should effect to obtain aid in a crop-protection program. A plan of procedure was approved and used for the conduct of the work during the season. The Chief of the Bureau was authorized to approve, on behalf of the Secretary, State Grasshopper Control Committees which were set up in accordance with the requirements. He was also authorized to approve the allotments of bait materials that could be made to meet the needs in the affected States and to employ individuals to be assigned in such States to assure adequate supervision as to the use of such materials. These allotments were based on relative needs as indicated by the grasshopper survey and subsequent developments as to infestation.
>
> States participating in the cooperative programs appointed a special Grasshopper Control Committee, which was responsible for the designation of a trained entomologist or State agricultural official satisfactory to the committee and to the Bureau. . . . to act as its duly authorized representative in the capacity of State leader in grasshopper control and to be responsible to such committee for coordination of State activities, establishment of a responsible State organization for grasshopper control, securing aid from local and

> county governing boards, and for the determination of the amount of bait materials needed in the affected areas of the State and submitting requests for such materials to the Federal office. The State leader was also responsible for the securing, at State or county expense, of necessary office space, clerical assistance, facilities for local truck transportation of bait materials, and county and local personnel. The establishment of a sufficient number of well-equipped and adequately-supervised bait-mixing stations, the keeping of adequate records of bait materials shipped by the Federal government for local use and an individual record of bait delivered to farmers, and effective supervision of the distribution and application of the bait in a manner approved by the Bureau.... were additional responsibilities of each grasshopper control committee through its State leader. The Department's part in this cooperative program consisted in the purchasing and transporting of bait materials to designated distribution centers and in furnishing sufficient general supervision to see that the bait was applied in the most effective manner. Qualified employees of the department were used for the work, and they also were responsible for all expenditures from Federal funds.

Assurance of continuity of a project designed especially for control of incipient or emergency outbreaks of insect pests or plant diseases was strengthened by the passage, May 9, 1938, of Public Resolution No. 91 by the 75th Congress. This resolution amended a joint resolution made in 1937, as follows:

> That the Secretary of Agriculture, in cooperation with authorities of the States concerned, organizations, or individuals, is authorized and directed to apply such methods for control of incipient or emergency outbreaks of insect pests or plant diseases, including grasshoppers, Mormon crickets, and chinch bugs, as may be necessary. Any sums which may be appropriated for such purposes shall be available for expenditure for the employment of persons .. administration and supervision, surveys, and the purchase, transportation, and application of poison bait or materials and equipment for control . . . and for preparation of such poison bait or materials for application, and such other expenses as may be necessary. Materials and equipment for the control of such insect pests and plant diseases may be procured with any sums appropriated to carry out the provisions of this joint resolution ... and the transportation thereof may be under such conditions and means as shall be determined by the Secretary of Agriculture to be most advantageous.... There are hereby authorized to be appropriated annually such sums as may be necessary to carry out the provisions of this joint resolution.

The Bureau provided supervisors to direct control operations in all the infested States. All area supervisors were on duty in their field assignments by the middle of March and all district supervisors by mid-April.

Colorado

The costly battle of 1937 and the apparent inevitability of an even larger one in 1938 stirred the officials of Colorado to early preparation. Governor Teller Ammons *(40*)* wrote to F. A. Anderson, Director of Extension, February 23, as follows:

> The seriousness of the anticipated grasshopper infestation in 1938 cannot be overestimated.... The original appropriation by Congress for the control of grasshoppers and other insect pests in 1937 was $1,000,000, but that was supplemented late in the season

> by an equal amount.... Federal funds were used largely for the purchase of poison bran... and for its transportation. Information regarding the extent of Federal aid that might be anticipated and time of delivery of bait was not available, either during the time when plans were being developed for the campaign or during its progress. We were, therefore, compelled to utilize supplies only as received.
>
> The long delay in the organization of our forces and in the availability of adequate supplies of poison bait in 1937, over which we had no control, was a serious handicap and necessitated supplementary emergency assistance of unprecedented character, such as providing trucks and personnel from the State highway and military departments for transportation of supplies. Assistance of this character cannot be provided to any great extent, if at all, during the current year.
>
> ...Moisture conditions in eastern Colorado are more favorable now than during any spring since 1930. Every possible precaution must be taken to protect the crops that we now have good prospects of raising. This will require a most intensive campaign in grasshopper control. The success of the effort will depend upon careful execution of plans already formulated.... Men and trucks for the transportation of supplies from railroad destinations to mixing plants and to the field as needed will also be required. This will have to be a local responsibility. About all that can be expected from State and Federal governments will be our proportion of poison bait from funds appropriated by Congress and technical supervision and assistance in its proper use. Nothing that can now be foreseen is of such importance to the farmers and stockmen of eastern Colorado as the complete cooperation and financial assistance necessary to conduct a thorough grasshopper-control campaign....

The Colorado State Committee on Grasshopper Control consisted of the Director of Extension and the State Experiment Station and Extension entomologists. The Extension entomologist, Sam C. McCampbell, was designated by the committee as State leader.

The State leader conducted educational meetings early in the season with such groups as State legislators, State officials, county commissioners, commercial clubs, luncheon clubs, and farmers' organizations. He and Federal supervisors conducted educational and organizational meetings with county agricultural agents, farmers, and ranchers throughout the latter half of March and all of May. Plans were laid for immediate and extensive control operations as soon as the grasshopper eggs began to hatch. Mechanical spreaders were constructed by several cooperating agencies; mixing stations were placed in readiness for operation by WPA crews; local organizations contributed funds and labor; and many individuals donated their services. Individuals assisted in the location of egg beds, which were conspicuously marked so they could be readily located by control crews *(5*)*.

Baiting should have begun shortly after May 1, but cool, rainy weather delayed the start until May 10. The standard bait formula was used except in a few instances in late season when unsatisfactory kills were corrected by the addition of molasses to the standard bait. In the early season, bait in the proportion of 1 part bran to 7 parts sawdust was effective. Bait spreading was per-

formed by individual farmers and ranchers by voluntary action. Entire infested communities were baited, regardless of ownership, but for the most part all members of a community cooperated by working on the same day. About three-fourths of the bait used was dispensed by mechanical spreaders. Commenting on the success of the 1938 control campaign the State leader *(40*)* said: "This season's 'hopper set-up is the best we have had so far . . . and we feel confident that much better coordination will exist between State and Federal programs. . . ."

From voluminous accounts that appeared in the Colorado newspapers two typical items are briefed below:

On June 10 the Colorado Springs Evening Telegraph carried a report on preparations being made to launch a widespread campaign against grasshoppers within the week. The board of county commissioners on that day passed a resolution creating a county-wide grasshopper control district under the authority of C. N. Vickers, Extension agent, who was appointed grasshopper inspector. The inspector and those working under his supervision had the power to inspect all lands in the county for grasshoppers and to spread poison bait where it was needed.

On August 19 the Colorado Springs News summed up the campaign that had been going on since mid-May as one of the most successful, cooperative campaigns ever conducted in El Paso County. Very few grasshoppers were left at the time the item was written and further trouble was not expected. Although the infestation was much worse than that of the previous year, much less damage had been done to pastures and crops because of the campaign.

Dove *(5*)* said of the *longipennis* area: "Damage from . . . the migratory species became extremely heavy during July and August, especially after the harvesting of small grains during the latter part of July. Many areas in which the nymphs . . . had been controlled by baiting were reinfested by the flying adults. Every county which had been originally infested reported heavy flights. A sufficient number of 'hoppers apparently matured in isolated areas and places inaccessible for baiting, to reinfest the entire area and present a serious control problem for next year. . . . sporadic baiting . . . continued into September. Excellent results were obtained from baiting for adult *longipennis* in many instances, although their rapid flight prevented planning of large-scale operations. Baiting of adults concentrated for egg laying continued successfully even in late September."

Effectiveness and efficiency of control operations were improved because of experience gained in 1937, because it was possible to complete control plans and start work early, and because the supervision provided was increased in proportion to the problem expected. Even so, the 1938 fall survey, conducted after the control fight was over, indicated *(66*)* that 15,219 tons of bait should be spread to control *longipennis* the following year, or approximately 50 percent more than was used in 1938. The survey estimate for 1939 was as follows:

County:	*Acres infested*	*Tons of bait*
Adams	64,000	208
Arapahoe	46,080	150
Baca	737,280	2,396
Bent	23,040	75
Cheyenne	357,120	1,160
Elbert	167,040	543
Kiowa	264,960	861
Kit Carson	339,840	1,104
Las Animas	730,000	2,732
Lincoln	1,290,240	4,193
Otero	23,040	75
Washington	299,520	973
Crowley	230,400	749
Total	4,572,560	15,219

The Colorado State leader estimated *(66*)* that the range damaged by *longipennis* in 1938 varied from 4 percent in Fremont County, to 40 percent in El Paso County; and that the value of range grasses saved by baiting amounted to $544,499. He reported that 2,423,664 acres of rangeland were baited.

Following is an estimate of expenditures for the control program in Colorado in 1938:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1]	
Materials (cost and freight):	
Bran, 2,480 tons at $21.26 per ton	52,725
Sawdust, 7,445 tons at $6.01 per ton	44,744
Sodium arsenite, 99,250 gal. at $0.315 per gal.	31,264
Supervision (salaries, travel, expense)	15,880
Total	144,613
Other: [2]	
Soil Conservation Service	25,355
Works Progress Administration	116,428
Total	141,783
Total expenditures by Federal Government	286,396
State Government: [2]	
Extension Service (salaries, travel, expense, exclusive of county agents)	5,118
County Governments: [2]	
Materials, rents, transportation, equipment	58,297
Mixing, 9,925 tons bait at $2.75 per ton	27,294
Total expenditures by County Governments	85,591
Individuals: [1] [2]	
Cash, materials and equipment	2,395
Spreading of 9,925 tons bait by ranchers, at $13.00 per ton	129,025
Total expenditures by individuals	131,420
Total expenditures from all sources	508,525

[1] Based on data in Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(5*)*.

[2] Based on data in Annual Report, Colorado State Leader of Grasshopper Control *(40*)*.

New Mexico

The fall survey in New Mexico in 1937 indicated that a significant increase in the control program would be necessary if the *longipennis* infestations were to be curbed or reduced in 1938. Surveyors had located 30 egg beds in Colfax County, 23 in Harding County, 2 in Mora County, and several in northern Quay County, and estimated that there were between 200 and 300 in Union County. Survey personnel had been insufficient to find and delineate all egg beds. Those located varied in size from 1 to 20 acres each. One surveyor said *(14*)*: "The southern third of Union County, the southern and eastern borders of Colfax County, the northern borders of Harding and Quay Counties, and the northeastern tip of Mora County contain quantities of *longipennis* egg beds. The grasshopper situation in these areas is expected to be very serious in 1938 unless some unusual act of nature prevents."

The cooperative control campaign was organized primarily on the basis that the Federal Government would furnish the bait materials delivered at county shipping points and the services of technical field supervisors. All other services were to be provided by the State and by the cooperating counties and individuals. H. L. Hildwein, Assistant Director of Extension, was designated as State leader of grasshopper control.

Aware of the control problem ahead, the State leader prepared early to meet it. He tells of the various measures taken to arouse interest in the program in his report of the year's work *(19*)*.

After Federal supervisors were assigned to New Mexico in the spring, organizational and educational meetings in the field were conducted by them in cooperation with State and county personnel. The area supervisor recorded two meetings at Springer that were the impetus for the formation of a citizens' committee, representing the infested counties. Of these meetings, he said *(31*)* that both were well attended by the committeemen as well as the county agents from the five northeastern counties; that in April, at the first meeting, plans for securing and handling sawdust were formulated; and that following the first meeting some organizational work was initiated that "began to get the people 'hopper-minded." He went on to say:

> From these meetings grew the citizens' organization which raised money locally, built spreaders, and put spreading crews in the field . . . concerted effort by the communities was the mode of the day from the time baiting operations started until the last sack was scattered. Each of the various communities . . . was divided into four sections. Each quarter was assigned to some resident who was responsible to the community leader. The man in charge of the quarter reported to the community leader such things as the location of new egg beds, migratory bands, and the needs of operators insofar as bait, spreading equipment, or help was concerned. It was soon found that with all these small organizations working and each clamoring for the outside help available, there must be some sort of coordination. At a meeting of the delegates . . . it was decided to elect a coordinator for the entire area. Albert Mitchell was elected to the post. The Governor then appointed Mr. Mitchell as coordinator of all agencies working on 'hopper eradication. The work then moved smoothly.

The selfless cooperation of all interests in the infested area is described by the area supervisor *(31*)*:

> Bait mixing was done by WPA labor under the supervision of... county agents and other Extension Service workers or at a few places by crews of farmers before WPA crews could be started. The townspeople donated money, time, automobiles, gasoline, equipment, and moral support to the operators. The State Highway Department built a number of bait spreaders and furnished trucks to pull and service some of them... all available equipment was pooled for the big drive. The operators in Colfax County which is more densely settled than the other four counties... cleaned up the infestation in their county fairly early. These people kept moving eastward into Union County. With the Union County people working southward and westward, the attacking elements converged at about the center of the infested area in Union County. Quay County, with... help from the Farm Bureau locals and... from people in the uninfested portion of the county, cleaned up its infested area rather early in the season. There, the people kept moving northward into Harding and Union Counties, baiting all egg beds and bands of nymphs as they proceeded.
>
> Cooperation was unbelievably good thruout the whole area. The people all went into the fight with the idea that if farm and ranch operators lost their fight against the 'hoppers the area in general would be bankrupt. The Santa Fe Railway hauled water to mixing stations and loaned bunk cars for crews in out-of-the-way places. Merchants sent their delivery cars to the country to pull spreaders. Professional men hired men to work as spreader tenders and sent their automobiles to pull spreaders. In short it was a complete mobilization of the whole area.

According to Hildwein *(19*)*, the standard formula for bait was followed until about mid-June, and then upon advice of J. R. Parker, the bran-sawdust ratio was changed to 1 to 5. Hildwein said, "Concrete mixers came into general use over the entire *longipennis* area. They considerably improved the quantity and quality of bait. . . . In spreading the bait, five or more spreaders worked together as a unit assigned to a given section. A scout, or the man in charge of the community quarter, reported where the egg beds or bands of nymphs were, and assisted the foreman in detailing spreader units to the best advantage. Infested areas were poisoned regardless of ownership, with few exceptions when, fearing crews might be careless, owners preferred to spread the bait on their own land. Highway rights-of-way were treated by the spreader crews whenever needed. Nonresident owners were requested to donate money to the cause but an infested area was treated whether or not the owner responded. . . . Nearly 400 mechanical spreaders were used throughout the entire area. Considerable baiting was done by hand in rough, rocky country, and in draws where nymphs congregated in great numbers. . . ."

"First hatching," Hildwein's report says, "occurred in the southern tip of the infested area in Quay and Union Counties during the first week of May. Hatching then was delayed by a few days of unfavorable weather and was not complete in the area as a whole until the third week in June. . . . The first flights, coming in with a wind from the north, were observed June 25. From then until July 7, each time a cool breeze blew from the north it was accompanied by a small flight of 'hoppers. During the month of July all of the adult 'hoppers moved south from the

infested area. By August 1, only an occasional 'hopper could be found in places where, during baiting operations, nymphs had run as high as 100 to 1,000 per square yard." The supervisor concluded that areas south of those where baiting was done in 1938 would present a serious control problem in 1939.

Dove *(5*)* summarized the season's activities and results as follows:

> Large-scale baiting operations commenced in the southern half of the infested area during the third week in May at which time some migrations from egg beds were beginning.... Baiting during the latter part of May and June continued at top speed, with mixing stations operating 24 hours per day, 7 days per week.... By the end of June effective control had been obtained and mixing stations were reduced to producing only enough bait to supply mopping-up crews, which continued to poison the remnants of the once large bands of grasshoppers.... At the close of the first week in July, baiting for *longipennis* had practically ceased as the small numbers remaining were so few and scattered that control measures were not justifiable.... the Bureau rendered further assistance... by furnishing truck hire to haul... sawdust from the mountains to the mixing stations. By the middle of August, heavy spotted infestations of adults were again found in the northeastern counties, concentrating for oviposition, which was well in progress. Baiting [adults on egg beds] began during the first part of August and continued through September. Excellent results were obtained and many concentrations were almost completely wiped out before extensive oviposition occurred. However, it was apparent that a serious control problem would be encountered in this area again next year.

The press kept the public informed of the control program in New Mexico in 1938. Several news items, briefed below, are typical of the many items that appeared in newspapers during the spring.

The Clayton News on May 25 reported that plans were being made by city men, county commissioners, and others to work out financial aid for the fight against the grasshoppers hatching out in the section around Clayton.

On May 26, the Albuquerque Tribune told of the emergency production of mechanical bait spreaders being started in the highway shops of the State, under personal supervision of the Governor and the Assistant Highway Engineer. According to the report, it was expected that 40 spreaders would be built for use in the northern counties of the State. The State was financing the construction of poison spreaders from "funds from several departments," according to the Governor.

The Amarillo Daily News, June 6, told of emergency donations being made by individuals and business organizations to help fight grasshoppers in five New Mexico counties. According to the item, the money was needed to help "five counties hard-hit for funds to fight the worst grasshopper plague in history." The new funds would assure an extension of the control work that had been carried out on an emergency basis for weeks.

Kurtz *(20*)* said that 190 homemade and highway spreaders were used in Union County, that highway trucks pulled spreaders, and that the Highway Department furnished a truck-mounted electric welder, and operators to repair spreaders, including those privately owned, wherever needed in the field.

Following is an estimate of expenditures for the control program in New Mexico in 1938:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1]	
Materials (cost and freight):	
Bran, 1,966 tons at $21.26 per ton	41,797
Sawdust	1,000
Sodium arsenite, 83,375 gal. at $0.315	26,263
Supervision (salaries, travel, expense)	8,600
Total	77,660
Other:	
Works Progress Administration [2]	36,100
Civilian Conservation Corps [3]	9,600
Soil Conservation Service [3]	600
Production Credit Association [3]	2,700
Total	49,000
Total expenditures by Federal Government	126,660
State Government:	
Extension Service: [2 3]	
Supervision (travel, clerical, exclusive of county agents)	7,000
Wind erosion funds	29,000
State Highway Department, National Guard, and other State agencies [3]	60,000
Total expenditures by State Government	96,000
County Governments: [3]	10,496
Commercial and civic clubs (cash) [3]	2,000
Individuals: [1 3]	
Subscribed through citizens' committee	15,000
Ranchers (cash)	1,777
Ranchers (spreading 7,786 tons bait at $13,00 per ton)	101,218
Total expenditures by individuals	117,995
Total expenditures from all sources	353,151

[1] Based on data in Annual Report, Bureau of Entomology and Plant Quarantine *(5*)*.
[2] Based on estimate supplied by the New Mexico Leader of Grasshopper Control.
[3] Based on data in the Annual Report of the New Mexico State Leader of Grasshopper Control *(19*)*.

Oklahoma

Specific records on the control of *longipennis* in Oklahoma in 1938 have not been found. The State leader's report indicated that, although adults migrated until they occurred in threatening numbers as far eastward as Beaver County, control was undertaken only in Cimarron County.

Dove *(5*)* said that heavy infestations of the first four instars, which required control measures, were found in the Panhandle counties. "When this species began to reach maturity during the third week of June, baiting had reduced their numbers so that they were of little importance. . . . General baiting was carried out in this area with remarkable success against adults concentrated for egg laying."

Stiles *(75*)* said: "There was practically no damage until late in the season when *longipennis* flew in from some other part of the

country. During the latter part of July and the first part of August enormous swarms of migratory grasshoppers appeared in Texas and Cimarron Counties and we had to begin poisoning operations. . . . Around July 20 the first flights were observed in Cimarron County. Later flights occurred almost daily and continued until September 1. . . . this species is generally distributed throughout the Panhandle counties."

That the infestation, important locally, was not countywide was indicated in the July 28 issue of the Boise City News: "During the past ten days an influx of hordes of grasshoppers along the Colorado State line has created a serious situation for Cimarron, and a poisoning campaign to stop the menace was launched Tuesday by County Agent W. E. Baker and landowners in the affected area. 'These are the same grasshoppers,' Mr. Baker said, 'which have infested the county the last two years, and are known as the long-winged migratory grasshopper. . . . only in a few places have they collected in sufficient numbers to justify poisoning.' "

Following is an estimate of expenditures for the control program in Oklahoma in 1938:

	Dollars
Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (cost and freight):	
Bran, 14 tons at $21.26 per ton	298
Sawdust, 41 tons at $6.01 per ton	246
Sodium arsenite, 550 gal. at $0.315 per gal.	173
Supervision	200
Total expenditures by Federal Government	917
State Government: [2]	
Extension Service (salaries and expenses exclusive of county agents)	250
Individuals: [2]	
Spreading 55 tons bait by ranchers at $15.00 per ton	825
Total expenditures from all sources	1,992

[1] Based on data in the Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(5*)*.

[2] Based on the Annual Report, Oklahoma State Leader of Grasshopper Control *(75*)*.

Texas

Control of the High Plains grasshopper in the counties of the Texas Panhandle was organized in accordance with the understanding agreed to by all States with which the Federal Government cooperated in 1938. Bait materials were provided chiefly by the Bureau and mixed into bait by counties. Technical supervision was provided by the Bureau and by the Extension Service through the State leader. Counties had the responsibility of hauling bait to distribution points, and the program outlined relied upon ranchers and volunteers to scatter bait on the infested lands.

Knowledge of the infestation expected in 1938 was gained from the adult and egg survey conducted in the fall of 1937. At that time the State leader wrote *(63*)*: "This species has been present

in the northwestern corner of the Texas Panhandle all season. . . . Dallam County in the extreme northwest carries as many as 18 egg pods per square foot over considerable areas." In 1938, the State leader reported *(52*)*: "Meetings were held with businessmen, ranchers, and farmers in the late spring to consider the emergency facing Panhandle counties, brought on by an extremely heavy infestation by the migratory grasshopper, *Dissosteira longipennis.*"

When eggs began hatching in early May a determined control fight was made by individuals and community organizations. Toward the end of the month they realized that control work was not keeping abreast of grasshopper developments. Representatives from the four most heavily infested counties, Dallam, Hartley, Moore, and Sherman, met in Dalhart, Tex., June 8 and "selected Ted Houghton, Hartley County rancher and commissioner, to head the fight." Under Mr. Houghton's leadership, supplies of manpower and equipment were increased and greater cooperation was obtained throughout the infested area. Land owned by nonresidents in an infested area was baited by the field crews *(52*)*. "Efforts were especially concentrated toward controlling the infestation of *longipennis* before the grasshoppers became adult. . . . extremely good cooperation was received from individuals, local organizations, State and Federal agencies. Heavy baiting for the species continued through the first part of July. By that time most of the bands had been destroyed and only a few scattered individuals remained." *(5*)*

Areas that had been cleared of grasshoppers by well-coordinated baiting activities were soon reinfested by adults that flew in from elsewhere.

Dove *(5*)* said:

> Following the heavy migrations from the north and northwest into several Panhandle counties during the first part of August, baiting in nearly every Panhandle county increased during the latter part of the month.... Heavy baiting against grasshoppers concentrated for egg-laying and for the protection of fall-sown wheat continued throughout September and much of October. Good results were obtained and many concentrations of *D. longipennis* were destroyed before egg deposition occurred. Adult and egg surveys conducted in late August, September, and October revealed that small bands were present in most of the Panhandle counties and also in some additional counties to the south. The infestation of this species promises to cover an area many times larger [in 1939] than during this year.

Nearly 700,000 acres of land were baited. Cooperation was vastly greater than is specifically credited in official reports. Newspaper accounts showed that 40 National Guard trucks with drivers, 18 State Highway trucks with drivers, and numerous Soil Conservation Service trucks and pickups, were assigned to help in grasshopper control. WPA workers manned most of the mixing stations. Numerous counties, ranchers, and businessmen contributed automobiles, built bait spreaders, furnished supplies, and so forth.

Voluminous newspaper articles gave a more vivid and realistic account of the struggle for control than is to be found in official reports. Three typical examples are briefed below.

The Amarillo Daily News, May 29, said that "Money, men and machinery, Model T Fords . . . have been recruited in the greatest pest war in the history of the plains." Listed as cooperators in the war on grasshoppers were the Federal Government, county commissioners, Extension Service, businessmen, farmers, ranchers, city officials, and individuals.

On June 11 the same paper reported on the progress of the fight on grasshoppers in Dallam, Hartley, Sherman, and Moore counties. The fight on that day was concentrated in west Hartley County. It was estimated that in 2 days 250,000 pounds of poison mash would be spread by the 500 men working in the campaign. Within a few days the coordinator of the work hoped to have 300 mechanical spreaders distributing 300,000 pounds of mash daily. It was estimated that between half a million and a million dollars worth of damage had already been done by the grasshoppers in the four counties.

The Dalhart Texan on July 20 reported that more grasshoppers were flying into the Texas Panhandle from the north. One swarm was so large it took 40 minutes to pass over the town of Stratford.

Rangeland in the Texas Panhandle was not surveyed for the specific presence of *longipennis* in 1937. However, in the survey of croplands the species was found in 7 of the Panhandle counties. The estimate of bait needed to control grasshoppers, including *longipennis,* in 1938 was 1,118 tons *(65*)*. Since it was known that the species had spread alarmingly and was dominant in several counties, rangeland that year was surveyed after all control operations had ceased. The survey revealed that eggs had been deposited in 22 counties and that the total area infested involved 4,127,000 acres. From the survey data it was estimated that 13,428 tons of bait *(64*)* would be needed to control the infestation of *longipennis* expected in Texas in 1939.

Following is an estimate of expenditures for the control program in Texas in 1938:

	Dollars
Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (cost and freight):	
Bran, 956 tons at $21.26 per ton	20,325
Sawdust, 2,867 tons at $6.01 per ton	17,231
Sodium arsenite, 38,170 gal. at $0.315 per gal.	12,024
Supervision (salaries, travel, and expense)	4,500
Total expenditures by the Federal Government	54,080
State Government: [2]	
Extension Service (salaries, travel, expense exclusive of county agents)	1,000
County Governments: [1 2]	
Materials (cost and freight):	
Sawdust, 1,586 tons at $6.01 per ton	9,532
Mixing, 3,435 tons bait at $3.00 per ton	10,305
Total expenditures by County Governments	19,837
Individuals (spreading 3,435 tons bait at $13.00 per ton) [1 2]	44,655
Total expenditures from all sources	119,572

[1] Based on data in Annual Grasshopper Control Report, Bureau of of Entomology and Plant Quarantine *(5*)*.

[2] Based on data from the Annual Report, Texas State Leader of Grasshopper Control *(52*)*.

Official records available do not specify or itemize materials and services furnished in the Texas Panhandle in 1938. It is estimated that 90 percent of the work there was directed toward control of *longipennis*. Calculations of expenditures, therefore, are based on the supposition that 90 percent of the bait spread in the 7 counties infested by this species was used in its control.

1939

Although this publication deals exclusively with the High Plains grasshopper, the migratory grasshopper *Melanoplus mexicanus mexicanus* Saus. (formerly called the lesser migratory grasshopper) must be mentioned here briefly because it had to be taken into account in the grasshopper control program in 1939.

Grasshopper control in 1938 had fallen short of expectations because the migratory grasshopper crawled and flew from idle or waste land where control had not been practiced to areas where crops had been protected by baiting. The migratory grasshopper had been the principal injurious species in the Great Plains as a whole. In the northern Great Plains States, where many agencies were organized for control as they never had been before, many farmers watched helplessly as crops they had saved were destroyed by grasshoppers that had migrated to their fields from idle land and depleted range.

The migratory grasshopper alone turned the tide of a battle almost won to partial or even complete defeat in widespread crop areas of the northern Great Plains. Also, some range areas of the High Plains that had been cleared of dangerous populations of *longipennis* were reinfested by *mexicanus* adults that flew from afar. It became apparent that protection of range areas in the High Plains in 1939 would require control of both of the migratory species.

Clearly the control program that had been so strengthened by Congressional action in 1938 needed further bolstering to accomplish its goal. Farmers, ranchers, State cooperators, and Federal personnel all felt that protection of control already accomplished would be necessary to the functioning of a completely successful program. Cooperators' views, mainly in accord on the correction needed but divergent on how it should be accomplished, were reasonably solidified in a proposed plan of work *(25*)* presented to all cooperators by the Chief of the Bureau, December 15, 1938. His statement was:

> This program varies from that of 1938 only in minor detail... except that in areas where, due to sparse human populations or the presence of large areas of public, abandoned, or reverted land, it would be impossible for local persons to cope with the manpower demands to carry out a successful program. In those areas a joint Federal-State program is proposed which will undertake responsibility for the application of bait.... Emphasis on Federal cooperation will be placed on crop protection... however... activities directed against the two principal migratorial species, namely, *longipennis* and *mexicanus*, will be extended to concentration grounds of nymphs and adults in areas where effective control is believed to

be feasible and practicable.... Control operations will embody the *longipennis* area comprising parts of Colorado, New Mexico, Oklahoma, and Texas and certain areas in Montana, North Dakota, South Dakota, and Wyoming known to be generally infested with *mexicanus*....

Subsequent developments that affected the planning and execution of the grasshopper control program are clearly indicated in the statement *(79*)* made March 6, 1939, by the Chief of the Bureau to cooperating agencies:

> The estimate for funds required to cooperate with States to combat grasshoppers provided for a material expansion of the program that was carried on in previous years, to provide for control of grasshoppers on idle farm land and adjacent rangeland, for the purpose of preventing grasshoppers with migratory tendencies from later moving into crop lands. This change in the program was the cause for the material increase in the amount of funds estimated as necessary to control grasshoppers during the coming crop season.
>
> Since it has become impossible for the Department to carry out the program originally contemplated... entailing operations in the grasshopper-control program, first attention will be given to the protection of crops. This decision is fully supported when consideration is given to the entire area over which grasshoppers are expected to occur in outbreak numbers, and the proven benefits in protecting crops from these pests through work done during previous seasons. Funds allotted for grasshopper work in addition to the amount needed for crop protection will be used to cooperate with States in combatting migratory species of grasshoppers. The lesser migratory species of grasshopper, which occurs in idle farm lands in parts of Montana, Wyoming, North and South Dakota, presents, in our judgment, a menace greater to crops than do migratory grasshoppers in other sections. It is proposed that requirements in this area will receive proportionately greater attention than that directed toward the control of long-winged grasshoppers in the range areas of Colorado, New Mexico, Oklahoma, and Texas.....
>
> In the control of the migratory species which occurs in the southwest plains States of Texas, New Mexico, Oklahoma, and Colorado, first attention will be directed to control work in the areas immediately adjacent to cultivated crops.... When conditions and resources permit, an effort will be made to locate the egg beds in sections of the area more removed from crops to determine those centers where grasshoppers occur in such numbers as to threaten crops by migration and apply control on such sections insofar as facilities and materials permit.
>
> The revision of the contemplated allotments which it has been necessary for the Department to make on the basis of the total sum now available is shown in the tabulation which follows. If natural or other factors intervene, adjustments will be made to the best interests of the work.

Federal funds appropriated, insufficient to finance the control program needed and planned, were exhausted by June 1 at the peak of control operations. Congress made an additional appropriation June 13 as indicated by a press article datelined "Washington, AP, June 14, 1939" which read: "Financed by an emergency appropriation of $1,750,000 the agriculture department redoubled efforts today to check a grasshopper outbreak which threatens to rival destructive scourges of the past. . . . The agriculture department already has spent nearly $3 million in control work this year. It has distributed 175,000 tons of poison bait and has hired thousands of workers to help farmers spread

it. These efforts proved insufficient and Congress, heeding appeals of farmers, voted an additional $1,750,000. President Roosevelt signed the measure yesterday."

This account refers to Public Resolution No. 22, 76th Congress, entitled, "Making an additional appropriation for the control of outbreaks of insect pests."

Control plans and control work in all the cooperating States in the *longipennis* area, as in former years, used all the local and State cooperation available (fig. 26). In addition, labor and equipment provided out of Federal funds were used to correct the weakness in programs of former years (fig. 27). This assistance permitted baiting more completely all heavily infested areas. More bait coverage and buildups of natural enemies served to prevent major flights and reinvasion of areas already treated.

An important part in the success of control in 1939 is attributed to the services of special surveyors who kept control supervisors advised of developments; this knowledge enabled supervisors to keep abreast of control problems as they evolved. Two entomologists were assigned exclusively to *longipennis* survey, one in Colorado and Kansas, the other in New Mexico, Oklahoma, and Texas. Cooperating with control supervisors in their respective regions they made extensive observations in the spring to determine when eggs would hatch in specific localities; made repeated observations throughout the season to determine the rate of development, effects of natural factors, and the effects of control operations; and gathered comprehensive data on habits and life history. They directed and worked on the fall survey in which egg beds were located and marked to facilitate timely control when eggs would hatch in 1940.

An autogiro was used to spread bait on certain areas in rough terrain where it was impracticable to utilize ground spreaders.

Speaking of the area as a whole, Dove *(6*)* at the close of the control program, said:

> the long-winged migratory grasshopper hatched in beds involving from one to thousands of acres of rangeland. In controlling this species it was primarily necessary to locate the hatching grounds and spread poisoned bait so that the developing hordes of young 'hoppers would be destroyed before they could reach maturity or

BN-1950

FIGURE 26.—Trailer mechanical spreaders used by ranchers in applying bait.

BN-1949

FIGURE 27.—Federally paid crews applying bait in Dallam County, Tex., 1939.

> infest crops. This work was so carefully planned and operations were made so timely that... this season's work indicates that unusually successful results were obtained. The remaining 'hoppers were scattered so [before egg laying] that it was not economically sound to spread bait over the wide area involved.

Ranchers were alarmed at the prospect of failure of control efforts when Federal funds were exhausted at the height of control operations. They implored their representatives in Congress for additional assistance sufficient to complete the job. The following exchange of telegrams is illustrative of many similar instances in all of the infested States. In this case, telegrams from Congressmen were elicited by an inquiry made by the editor of the Eastern Colorado Leader. These were printed in the paper of June 13, 1939:

> Western Union, Washington, D. C., 6:19 p. m., June 9, 1939.
> Deficiency Appropriation Bill which passed House on January 23 nineteen-thirty-nine contained for pest control including grasshoppers two million dollars. Senate increased this amount to five million four hundred seventeen thousand. House refused to concur in increase. Compromise was reached in conference fixing amount at three million and there was on hand unexpended for grasshopper control from funds for current fiscal year seven hundred thousand and also approximately one million dollars worth of materials. This item together with many other items are before conference committee for adjustment. Agriculture Bill may not be passed for some days. Senate appropriation committee yesterday passed resolution providing for appropriation two million four hundred seventeen thousand for grasshopper control. If a similar or same resolution is passed by the House and signed by the President needed funds will be provided even though Agriculture Bill delayed in passage. House insisting budget estimate be secured before they agree to additional appropriation and result is so far as Senate is concerned everything has been done that can be done to provide money for grasshopper control and problem now awaits action by the House. Resolution as passed by the Senate yesterday provides independently for appropriation bill.
>
> Alva B. Adams and Edwin C. Johnson

Washington, D. C., 2:31 p. m., June 10, 1939.
Additional funds have been approved by Director of Budget for grasshopper control. Funds will be available early next week.

Fred Cummings, M. C.

Washington, D. C., 2:52 p. m., June 12, 1939.
Immediate appropriation of one million seven hundred fifty thousand dollars passed both Houses of Congress today for grasshopper control. Matter now awaits President's signature.

Alva B. Adams and Edwin C. Johnson

Washington, D. C., 1:55 p. m., June 13, 1939.
President signed appropriation for one million seven hundred thousand dollars for grasshopper control.

Alva B. Adams and Edwin C. Johnson

The foregoing telegrams refer to the legislation that became Public Resolution No. 22, 76th Congress, previously referred to.

Colorado

Realizing that for the third consecutive year Colorado faced a fight bigger than the year before to control the High Plains grasshopper, the State leader carried on educational and organizational work from midwinter until the time for control *(41*)*. Meetings were held with State legislators and State officials, county commissioners, farm organizations, commercial clubs, business clubs, fraternal organizations, grasshopper control committees, and county agricultural agents.

The Bureau established a temporary field office at Pueblo and employed a General Supervisor and six other supervisors to assist him at strategic locations in the State. L. G. Davis, the General Supervisor, said *(3*)*:

> Starting April 3, 1939, a series of meetings was held in counties in the *D. longipennis* area with county commissioners, county leaders, and county grasshopper control committees. The purpose of these meetings was to coordinate the activities of county, State and Federal agencies and to determine the extent of participation by each agency. . . . In some cases it was necessary to follow up the first meeting with a second. . . . Several educational meetings were held in each county. These and field demonstrations in most of the counties were handled by county extension agents and by district supervisors.
>
> The 1939 season was entirely different from the 1938 season. In 1938 it was warm enough for a day or so in the early spring so that a part of the eggs would hatch. But, before poison could be applied, it would turn cold and the 'hoppers would not feed but would spread considerably. Then, after a day or so of cold weather it would turn warm to hatch a new band and then turn cold again for a day or so. Weather of this type makes it very difficult to get early control. Weather conditions favorable to maximum control results prevailed in 1939.
>
> Farmers were first encouraged to control 'hoppers on their own land and then to extend their efforts to adjacent land, regardless of ownership. Federal bait spreading was withheld until such a time that the situation was getting beyond control of local people. At that time Bureau-paid crews were sent into the field to get the job done, regardless of local participation. As soon as paid crews were placed in the field, 'hoppers were controlled wherever they were found, regardless of ownership of land, except in rare instances where the owner refused to have bait spread on his land. . . . Permission was always obtained from owner, agent, or renter.

Depletion of funds in early June seriously interrupted a going program. No State funds were available to fill the breech until new Federal funds permitted full operation again. Counties and individuals, already extended, could do little more, so laborers and trucks were idled for nearly a week. The description of the resumption of work in Lincoln County, as published in the Eastern Colorado Plainsman and Range Ledger, June 16, is illustrative of the situation in all other counties in the infested area.

All labor for mixing bait was paid for by the county, the Works Progress Administration, or by the Bureau. The formula followed in preparing bait was: Millrun bran, 1 part; sawdust, 6 parts; sodium arsenite, 2 quarts per 100 pounds of dry bait. Most nymphal baiting had ceased by July 15. Fall baiting, directed against adults congregated for egg-laying, was carried on in Otero, Cheyenne, Pueblo, Lincoln, and Las Animas Counties from the time adults began to congregate until August 25 *(3*)*. Scharff *(56*)* said:

> Baiting on adult 'hoppers in different areas gave greatly varying results. . . . In Lincoln and Las Animas Counties during the first half of August the kills were good, ranging as high as 60% for one baiting on some egg beds. Thereafter kills became smaller and by the end of August kills of less than 10% were not uncommon. The better results in both instances during the first part of the month were achieved in areas where the grass was short and dry. Toward the end of the period, the 'hoppers moved into regions where their natural food was green and in very good condition. Baiting on the Otero county infestation during August achieved about the same poor results as were found in Lincoln and Las Animas counties during the last week of that month. The grass there was in good condition for the whole month. It was found that gravid females ate the poisoned bait as readily as nongravid individuals.

In Colorado, as in other States, methods of control other than baiting had been tried and found to be impracticable, too costly, or too slow. Public reaction to organized grasshopper control was predominantly favorable but correspondence or newspaper articles of a critical nature were not uncommon.

One critic, for example, in a letter to the Denver Post, published June 11, 1939 pronounced the government control program "a miserable failure." He added that if one-tenth of the money that had been spent on poisoning campaigns in the foregoing 5 years had been spent on blow torches and if the torches had been properly used "there would not be a migratory 'hopper left in the western states." The best way to get rid of grasshoppers according to this writer was to burn them out with the blow torch early in the spring.

Voluminous press articles kept the public informed of plans, progress, and accomplishments. Three examples are briefed below.

The Pueblo Star-Journal on April 16 reported that survey parties had been at work for several weeks in the entire eastern part of the State searching for grasshopper egg beds.

The Pueblo Chieftain on April 29 told how the old western spirit of "everybody help" would be the principal weapon in the 1939 campaign against migratory grasshoppers in eastern Colorado. The district supervisor for the migratory grasshopper

control program of the U. S. Bureau of Entomology and Plant Quarantine was quoted as saying that the cooperative volunteer effort by residents of the infested areas would prove as valuable as the bait materials being used as "ammunition."

On May 16 the same paper reported that eastern Colorado's war on migratory grasshoppers was underway in each of the 13 counties where egg beds had been found. Federal experts had reported that the hatch of grasshopper eggs would be completed virtually at once and quick action would deal a damaging blow to the grasshopper hordes early in the season.

Bait was applied on 2,913,018 acres of range in the *longipennis* area. Bureau-paid spreading was as follows *(54*)*:

	Tons	*Acres*
Spring baiting	9,448	960,457
Fall baiting	2,314	241,323
Total	11,762	1,201,780

Ninety-five percent of the bait used in seven Colorado counties was distributed by mechanical spreaders provided by several cooperating agencies, as follows:

County	Number of spreaders provided by specified agency				
	County	Individuals	Bureau of Entomology and Plant Quarantine	Extension Service	Total
Baca	33		50		83
Cheyenne	11	4	12		27
Crowley	6	20	30	2	58
Elbert	19		3		22
Kit Carson		15	9		24
Las Animas	19		53	1	73
Lincoln	5	20	105	7	137
Total	93	59	262	10	424

At the close of the 1939 fall survey, Scharff *(56*)* said: "There are six counties in Colorado that are known to have areas infested with *longipennis* egg beds, namely, Otero, Lincoln, Las Animas, Pueblo, Cheyenne, and Adams. Ninety-eight egg beds have been found, totaling 1,910 acres. These counties have a total probable infested area of 164,000 acres." Some egg pods were known to be scattered also between egg beds.

At the end of the control season Dove *(6*)* said:

> The excellent results of control measures by federally paid and volunteer crews in the *longipennis* area had so reduced the numbers of these 'hoppers that those remaining were becoming widely scattered and making baiting impractical. The populations were so diminished that the light flights which occurred were of slight importance and produced practically no damage. Farmer baiting ceased almost entirely in the migratory counties the first week in July and all federal control units were stopped on July 15, at which time no large bands of *longipennis* could be found.... Oviposition by *longi-*

> *pennis* began on August 1. Baiting continued until about August 30, when it ceased entirely for the season. Very good results were obtained from this late summer baiting and the potential infestation for 1940 was greatly reduced. Those egg beds which were deposited in spite of the baiting program were carefully surveyed, marked, and mapped. Sarcophagid parasites and large bands of hawks . . . in some instances, quickly eliminated the few [bands of] *longipennis* hoppers remaining after the cessation of baiting activities.

Commenting on the impressive population reduction Mickle *(3*)* said: "The *longipennis* program was deemed extremely successful not alone by personnel connected with the administration of the program but also in the opinion of the people closest to the infestations, namely, the farmers and ranchers, county extension agents, county commissioners, and local people. It is true that the coming spring will see a few areas infested with this 'hopper again but, considering the enormous area . . . infested in 1939, the 1940 infestation seems just a 'drop in the bucket.'"

The State leader *(41*)* said:

> The largest outbreak of grasshoppers in the agricultural history of the State was met with much the most efficiently organized and conducted campaign yet carried out in the State. The program of work was conducted in the migratory area for the first time along the lines that the State committee had advocated for the past three years. The results have been most outstanding. In 1938 the survey showed over four million acres infested with *D. longipennis*. This season's campaign cut this infestation down to where the 1939 survey shows a probable infestation of less than 100,000 acres.

In the *longipennis* area some bait was used for control of other species of grasshoppers on croplands and against *Melanoplus mexicanus* on rangeland. In the following tabulation it is estimated that 75 percent of the Federal expenditures for voluntary control and ninety percent of the expenditures for paid control are chargeable to *longipennis*.

Following is an estimate of expenditures for the control program in Colorado in 1939:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1] [2]	
Materials (cost and freight):	
Bran, 1,176 tons at $22.69 per ton	26,683
Sawdust, 7,717 tons at $5.98 per ton	46,148
Sodium arsenite, 88,618 gals. at $0.2798 per gal.	24,795
Purchased bait spreaders, depreciation [3]	3,600
Purchased trucks, depreciation [3]	6,700
Operation and maintenance of purchased trucks	40,500
Operation and maintenance of trucks lent by other Federal agencies	4,261
Freight on equipment	7,200
Supervision (salaries, travel, expense)	26,100
Headquarters expense	2,254
Foremen, truck drivers, laborers (wages)	81,055
Airplane operations (baiting $1,000; scouting $441)	1,441
Total	270,737
Works Progress Administration: [1]	61,269
Total expenditures by Federal Government	332,006

(Remainder of tabulation and footnotes on next page.)

State Government:	
Extension Service (salaries, travel, expense exclusive of county agent): [4]	5,000
County Governments (bait mixing, storage, rent, clerical) [4]	20,115
Individuals (spreading 4,759 tons bait by ranchers, at $7.39): [1]	35,169
Total expenditures from all sources	392,290

[1] Based on data from the Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(7*)*.
[2] Materials calculated as 75 percent used for voluntary control and 90 percent for paid labor control; other items as 90 percent used for paid labor control except hire of foremen, truck drivers, and laborers, and airplane operations which were charged entirely to paid labor control.
[3] 5-year useful life assumed.
[4] Based on Annual Report of the Colorado State Leader of Grasshopper Control *(41*)*.

Kansas

A small amount of federally paid work was directed against *longipennis* in Kansas in 1939. The State leader said *(28*)*: "*D. longipennis* laid a few eggs in southwestern Kansas in 1938 but was not a pest at any time. . . . In one county the species was reported to be plentiful, but they disappeared before we could find them. . . . It is quite evident that the species will not become a pest in Kansas."

A survey conducted by Federal supervisors in early May indicated that dangerous infestations of grasshoppers were present in nine counties in southwestern Kansas and that farmers were unconcerned in controlling them. In some areas *longipennis* nymphs were intermingled with those of *mexicanus* and other species.

A paid-labor control program was hastily organized on roadsides and idle lands principally to prevent flights to new areas. The State leader reluctantly approved the program but said at its conclusion *(28*)*: "There was not much manpower in the eight-county area. . . . This baiting protected very little crops for there was not much in the area to be protected. The grasshoppers that were in the stubble that was planted to row crops ate up the new crops as soon as they came through the ground. There was little to be gained, so the farmers thought, in baiting. The area was much too large for the farmers to undertake; therefore, they welcomed the aid of the Federal government in this baiting program."

Three supervisors and 15 pickups with bait spreaders were assigned to the program for a period of about 7 weeks. The cost of the program, estimating that one-fourth of the bait used was for control of the High Plains grasshopper, was calculated as follows:

Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (cost and freight):	*Dollars*
Bran, 39 tons at $22.69 per ton	885
Sawdust, 118 tons at $5.98 per ton	706
Sodium arsenite, 1,575 gal. at $0.2789	439

Supervision (salary, travel, expense)	375
Truck operation and maintenance	750
Total expenditures by Federal Government	3,155
State Government: [1]	
Extension Service	50
County Government (mixing 158 tons bait at $3.00 per ton) [1]	474
Total expenditures from all sources	3,679

[1] Based on data from Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(7*)*.

New Mexico

Determined to make greater headway in control through added assistance available from the Federal Government, the State leader said *(20*)* that New Mexico State officials had the first of many educational and organizational meetings in early January. These were directed by the State leader, assisted by other Extension specialists and by county Extension agents who served as county leaders. Assistant county leaders were hired in counties where grasshopper infestations were heaviest. Thomas Owen of Clayton was appointed by the Governor as State Coordinator. Where infestations were especially severe county coordinators were appointed to promote locally effective action by all cooperators. Salaries and expenses of the State and county coordinators were paid out of State funds. He discussed operations as follows:

> Guided by the experience of 1938, when 25 mixing stations were operated in the migratory area, the number in 1939 was cut to 10. Baiting against nymphs was begun April 29 and completed July 15. Baiting was resumed to kill adults congregated for egg laying and continued as long as concentrations persisted.
>
> The State of New Mexico expended $51,400 from State appropriations in providing mechanical spreaders, sawdust, and personnel. On June 12, when Federal funds were exhausted, the State assumed the entire Federal payroll on spreading crews in the field. This, coming at a time when the campaign was in full swing, was an important factor in the final success of the program. Contributions were also made by the State Land Office, the State Highway Department, and the Adjutant General's office. The SCS made available three trucks for use in hauling bait and bait materials in Quay and Curry Counties. . . . Men and trucks from the CCC were used in hauling most of the sawdust used and loading it on cars for shipment. Fly camps were set up in the mountains near sawdust supplies for this specific purpose. Most of the sawdust in Quay County was unloaded from box cars and hauled to mixing stations by CCC enrollees and trucks. The Works Progress Administration had charge of the entire job of mixing grasshopper bait.
>
> Even though individual ranchers were encouraged to begin scattering bait on beds as soon as hoppers hatched, counties organized spreading crews on a community basis, and, starting from the outer edge of infested areas, worked toward the center. Bureau pickups were supplemented by light trucks hired from State funds. . . . Assignment of territory to spreader crews was a joint responsibility of county leaders and Bureau supervisors. As crews advanced from one area to another, the farmer or rancher who had been selected as contact man was placed in charge. He would contact the landowner ahead of the arrival of the crew and secure from him a man on

horseback to spot the armies of hoppers ahead of the crew. When crews had worked a considerable area, a State-employed man with a pickup was assigned to follow up to respread areas where kills had been unsatisfactory or where eggs had hatched late. Highways were repeatedly baited to intercept migrating bands crossing them. Railroads voluntarily reduced freight rates for sawdust and the C. and S. lent a tank car to a mixing station when local water ran out and, without cost, hauled water 10 miles.

Resley described operation plans and control results as follows *(54*)*:

In Union County farmers and ranchers spread bait as they saw need, but a definite plan was developed over the county as a whole with State and Federal spreading crews working together. Twelve crews of 5 units each were put in operation with a definite territory assigned to each. Crews were started on the outside of the infestation and worked abreast, making a clean sweep of the infestation as they progressed. Judging from the highly satisfactory results of this plan, it is believed that it offers the best possibilities for cleaning up a large sparsely inhabited area.

Federal crews of five units each were in operation as follows:

Union County	2 to 6
Harding County	1
San Miguel County	1
Guadalupe County	1 to 2
Quay County	1 to 6
De Baca County	1

State crews were confined entirely to Union County, which was faced with a larger infestation than all other counties combined. In this county State-hired crews worked 1,446 spreader days. In addition, the Tri-State project of the BAE supplied six spreading units for use in Union County during the spring and early summer campaign.

Comparatively little difficulty was encountered during the entire campaign in securing baiting of highways, railroads, and lands owned by non-residents. In Union County, spreader units were maintained by the State to bait county, state, and U. S. roads, with highly satisfactory results. No great problem ever arose with infestations along railroad rights-of-way. In such instances adjoining landowners assumed the responsibility of baiting such areas. No difficulty was met with in securing permission to bait lands owned by non-residents. This was sometimes done by State or Federal crews or more often by adjoining landowners.

With the exception of several periods of time in Quay County and Guadalupe County, baiting secured very high and satisfactory kills. No baiting was attempted until temperatures rose above 70° F. Below this point baiting secured very little results. Satisfactory results were obtained with bait until the temperature arose above about 95 degrees. Above that point 'hoppers, even though still active appeared to be indifferent to bait. Few negative results were ever obtained in Union County. Days were practically all warm enough to warrant bait spreading, and it was not until mid-July that temperatures rose high enough to prohibit spreading crews working on an 8-hour day with a break in the heat of the day.

In the lower, hotter altitudes of Quay and Guadalupe Counties the reverse was true. Hatching began April 21 and many days were cold and cloudy enough to prohibit spreading before noon. This period having passed, temperatures rose excessively high until at length spreading crews were started at 5:00 a.m. and were stopped usually by 10:00 a.m.

Hildwein *(20*)* said:

> Practically all bait was spread by mechanical spreaders.... 50 were supplied by the Bureau and about 235 were constructed by the State Highway Department, county grasshopper committees, and by individuals. Bait was spread on 1,072,561 acres of rangeland.

Some results of control work in New Mexico are shown in figure 28.

The Federal supervisor *(54*)* summed up the 1939 control campaign:

> Everyone who has expressed himself concerning the success of the 1939 control program has been enthusiastic over the outcome. For the first time in five years, Union County is free of migratory range 'hoppers. The outside boundaries of all known infestations at the present do not form an area 2 percent as large as that faced in the spring of 1939. A statement made by Mr. Roy Kimble, Union County rancher who has had to fight grasshoppers on his ranch in 1936, 1937, 1938, and 1939, is quoted: "The situation looked hopeless when 'hoppers began to hatch out all over my ranch this year. I was doing all I possibly could, but without the help I got this year, I would not have had a blade of grass left by the time the 'hoppers would be grown and fly away. As it is, I believe they did me very little damage." Mention should be made of the good results obtained by baiting adults on egg beds previous to extensive oviposition, with the end in view of not only reducing the extent of the infestation the following year, but also its intensity. A first-class example of the results could be seen on the Moon Ranch in Guadalupe County in 1939 where extensive baiting on egg beds had been done in the late summer of 1938. Adults had migrated into this ranch and had destroyed all grass on several square miles. Baiting was begun and a high percent of kill was obtained before extensive oviposition had taken place. In the spring of 1939 two spreaders run for a period of about ten days eliminated all that hatched, while elsewhere in the county baiting had to be continued for more than a month and a half longer.

Interest of the press in the control campaign was expressed in voluminous newspaper accounts. Two of these are briefed below.

On April 5 the Clayton News reported that 200 farmers and stockmen had met to hear plans for this year's fight against the grasshopper menace. A representative of the Federal Government who had been scouting grasshopper egg beds told the meeting that there were about 120,000 acres of beds in approximately 2 million acres in 5 counties.

On June 14 the same paper reported the following sequence of events: On the previous Saturday, Federal funds for killing grasshoppers had run out. The Governor immediately authorized that State funds be used to carry on the work. By Tuesday, an appropriation bill for an additional $1,700,000 for grasshopper control had been passed by Congress and signed by the President; the measure had been sponsored in Congress by the two New Mexico senators. It was expected that by Thursday or Friday the Federal government would assume the payroll for the grasshopper work in New Mexico. In the meantime, the work had not been hampered by loss of workers.

Following is an estimate of expenditures for the control program in New Mexico in 1939:

	Dollars
Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (cost and freight):	
Bran, 824 tons at $22.69 per ton	18,697
Sodium arsenite, 57,690 gal. at $0.2789 per gal.	16,090
Purchased bait spreaders, depreciation [2]	1,000
Purchased trucks, depreciation [2]	4,300
Operation of purchased trucks	25,800
Operation of trucks lent by other Federal agencies	1,323
Airplane operations (baiting, $300; scouting, $2,241)	2,541
Freight on equipment	5,000
Supervision (salaries, travel, and expense)	10,728
Headquarters expense	2,500
Foremen, truck drivers, laborers (wages)	28,148
Total	116,127
Other:	
Works Progress Administration	39,215
Civilian Conservation Corps	6,600
Soil Conservation Service	1,599
Forest Service	3,708
National Park Service	1,815
Bureau Agricultural Economics	1,800
Total	54,737
Total expenditures by Federal Government	170,864
State Government:	
Extension Service (salaries and expense exclusive of county agents) [3]	3,000
Governor's emergency appropriation [4]	51,400
State Land Office [4]	15,000
State Highway Department [4]	15,000
Adjutant General's Office [4]	1,500
Total expenditures by State Government	85,900
Individuals: [1] [3]	
Businessmen (cash contributions)	4,850
Ranchers (spreading 4,206 tons bait at $7.39 per ton)	31,082
Total expenditures by individuals	35,932
Total expenditures from all sources	292,696

[1] Based on data from Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(7*)*.
[2] 5-year useful life assumed.
[3] Based on Annual Report of the New Mexico State Leader of Grasshopper Control *(20*)*.
[4] Data from records in the Governor's office.

Oklahoma

In expectation of controlling a severe infestation of *longipennis* in Oklahoma in 1939, Beaver, Cimarron, and Texas Counties prepared by storing bait materials and readying mixing facilities. W. E. Baker, county agent of Cimarron County wrote in the Boise City News, March 23, 1939: "During the summer of 1938 the greater portion of the northwest part of the county was infested with the large migratory grasshoppers. We saw thousands of

BN-1946

FIGURE 28—Nymphs killed by baiting, Union County, N. Mex., 1939.

those grasshoppers depositing eggs . . . at that time. . . . This past week Mr. Roy Etter, my assistant, and myself made a personal investigation of this area in search of grasshopper eggs and found them to be there by the millions. The average in the worst infested area being 6 pods of 40 to 50 eggs each to the square yard. There are many, many acres in those egg beds that have this high infestation. . . . This means we are going to have grasshoppers by the multiplied millions in this county this year. It also means that the entire county must get ready to carry on this fight and cooperate . . . to combat this menace or else we will have an infestation sufficient to destroy practically all of our range pasture. . . ."

Summarizing control activities at the close of the season, the Federal supervisor for Oklahoma reported *(44*)*:

> Some community action was taken in Texas and Beaver Counties. Heavily infested areas were baited regardless of ownership.... Federally paid baiting crews worked... from May 18 until July 15. The county agents in the three infested counties expressed their belief that control work had been unusually successful when they said: "The heavy infestation of grasshoppers we had this spring, which appeared to menace all growing crops [Beaver County], has been virtually wiped out. Through past experience in 1937 and 1938 . . . I know this would have been impossible had we not had the assistance of the Bureau. . . ." "The *longipennis* grasshopper has been reduced to negligible numbers. The damage to range and cultivated crops [Cimarron County] has been reduced to a minimum. . . ." "This is the first year that Texas County farmers have had the cooperation of the Bureau. . . . with trucks and spreaders in their attempt to control the migratory 'hopper. . . . the past spring and summer's poisoning campaign has been a success...."

Following is an estimate of expenditures for the control program in Oklahoma in 1939:

	Dollars
Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (cost and freight):	
Bran, 59 tons at $22.69 per ton	1,339
Sawdust, 358 tons at $5.98 per ton	2,141
Sodium arsenite, 4,170 gal. at $0.2789 per gal.	1,163
Purchased bait spreaders, depreciation [2]	360
Purchased trucks, depreciation [2]	2,200
Operation and maintenance of purchased trucks	1,320
Supervision (salaries, travel, expense)	3,000
Freight on equipment	1,200
Headquarters expense	500
Airplane operations, scouting	441
Foremen, truck drivers, and laborers (wages)	4,424
Total	18,088
Other:	
Works Progress Administration	1,253
Total expenditures by Federal Government	19,341
State Government: [3]	
Extension Service:	
Salaries and expense, exclusive of county agents	1,000
Allotment from wind erosion control funds	5,000
Total expenditures by State Government	6,000
County Governments (cash expenditures) [3]	4,368
Individuals (spreading of 417 tons bait at $7.00 per ton) [1 3]	2,919
Total expenditures from all sources	32,628

[1] Based on data in Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(7*)*.
[2] 5-year useful life assumed.
[3] Based on data in Annual Report, Oklahoma State Leader of Grasshopper Control *(76*)*.

Texas

Texas organized to use fully the additional Federal assistance available for control of *longipennis* in 1939. Unexpected intervention of natural factors materially reduced the amount of control planned for. This is shown clearly by the fact that the bait used was only about 10 percent of the amount that had been calculated as needed. The bait estimate had been 13,428 tons; the bait used was 1,320 tons *(6*)*.

The State leader *(53*)* said: "The hoppers hatched in numbers as anticipated. For further aiding in what was expected to be a disastrous infestation in the Panhandle counties, interests there attempted to influence a State appropriation for a control campaign, but without success. . . . Circumstances not fully understood reduced the numbers of the long-winged hoppers early in the season and in connection with an intensive campaign of control, damage to crops and range was largely prevented. The species was so reduced in numbers that so far as discovered by careful investigation in all suspected counties [in the 1939 fall survey], no actual egg beds of this species now exist in Texas."

Spicer *(6*)* found that hatching had occurred about normally when he reported May 21 that "heavy concentrations of nymphs of *longipennis* were found in egg beds and rangeland. Nymphs numbering from 45 to 2,500 per square yard were observed." Factors effecting the marked population reduction were the influence of predators and weather conditions that prevailed after grasshoppers hatched in the spring. These are discussed specifically under the heading, Causes of Outbreaks and Their Subsidence, page 74.

It was not until after control was fully underway, immediately after eggs had hatched, that the effects of natural factors began to be noticeable, therefore such effects influenced the extent of the control program only later in the season. Spicer said *(73*)* that in heavily infested counties where Bureau spreading units operated, the county grasshopper committees, ranchers, and farmers arranged for community action in applying bait so that complete coverage of infested areas would be obtained. This was true in Hartley, Moore, Hutchinson, Dallam, Oldham, and Potter Counties (in which the principal infestations of *longipennis* occurred) where paid crews scattered bait. At the peak of the season there were 41 Bureau-owned pickups in the field, grouped in 9 crews. The drivers and helpers on pickups and spreaders were paid by the Texas Extension Service and by the Bureau. The spreaders drawn by the pickups were furnished by the Bureau.

W. A. Ohls reported *(6*)* that "Although Sherman County was heavily infested with *longipennis* in 1938, no outbreak occurred there this year. During the hatching period one small egg bed was found. This bed was never baited as the lark bunting completely controlled the nymphs."

According to Spicer, counties in many instances paid for unloading and storing bait materials. Other county expenses included repairing old spreaders and building new ones and hiring the mixing station foremen. Helpers on spreader units were paid part of the time by the county in Hartley and Hutchinson Counties. The Soil Conservation Service furnished trucks and drivers for unloading bait materials and hauling bait to spreader crews in Dallam and Moore Counties and mixing station labor for Hartley and Dallam Counties. The Works Progress Administration furnished the mixing station labor in most of the counties where *longipennis* was controlled. The Texas Extension Service paid the salaries of scouts in some of the counties. The railroads in the north Texas Panhandle and the State Highway Department baited rights-of-way in those counties where infestations warranted it. The county control organizations arranged for baiting land owned by nonresidents. Natural mortality of grasshoppers in certain areas enabled supervisors to shift equipment released there to augment control in other areas, thus accelerating completion of the entire control campaign. An example of this occurred in Hartley County where originally four crews were assigned. The assignment there of additional crews to combat the heaviest and most extensive infestation in the State assured complete control sooner than had at first seemed possible.

The *longipennis* population, on September 10, 1939, did not exceed one per square yard in any place and it usually was less *(6*)*.

At the close of control operations, John M. Landrum, general supervisor for the three-State area reported *(6*)*: "The grasshopper control campaign in the States of Texas, New Mexico, and Oklahoma against *longipennis* was most successful. At the beginning of the year there were roughly 6,835,000 acres actually infested in the three States. At the present time there are no actual egg beds in either Texas or Oklahoma, and it is our belief that there are only 12 sections infested with egg beds in New Mexico." (See fig. 29.)

Panhandle newspapers diligently kept the public apprised of developments and accomplishments as typified by two selections briefed below.

Amarillo Daily News, March 28, reported that surveys completed the day before showed there were enough potential grasshoppers in panhandle counties to eat every green thing. The coordinator of the control program in the northwest Panhandle in 1938 predicted the plague would be twice as severe in 1939 unless immediate steps were taken to poison the young grasshoppers.

The same paper on May 19 reported that the Rock Island Railroad was helping in the war on grasshoppers. The company had spread poison on its right-of-way from Amarillo to Liberal, Kans., a distance of 153 miles. A common box car had been equipped with

BN-1945

FIGURE 29.—Dead and dying nymphs congregated along an escarpment 12 hours after bait was applied. Potter County, Tex., 1939.

a mechanical poison spreader. The spreader distributed the poison on one side of the track going to Liberal and on the other side on the return trip.

Following is an estimate of expenditures for the control program in Texas in 1939:

	Dollars
Federal Government: [1]	
Bureau of Entomology and Plant Quarantine:	
Materials (Cost and freight):	
Bran, 330 tons at $22.69 per ton	7,488
Sawdust, 990 tons at $5.98 per ton	5,920
Sodium arsenite, 13,200 gal. at $0.2789 per gal.	3,681
Purchased bait spreaders, depreciation [2]	500
Purchased trucks, depreciation [2]	4,900
Operation and maintenance, purchased trucks	24,500
Operation and maintenance, trucks lent by other Federal agencies	209
Freight on equipment	3,000
Supervision (salaries, travel, expense)	6,900
Headquarters expense	1,500
Foremen, truck drivers, laborers (wages)	6,176
Airplane operations (scouting)	2,241
Total	67,015
Other:	
Works Progress Administration	3,753
Soil Conservation Service	1,500
Total	5,253
Total expenditures by Federal Government	72,268
State Government: [3]	
Extension Service:	
Salaries and expense exclusive of county agents	1,000
Allotment from wind erosion control funds	10,257
Total expenditures by State Government	11,257
County Governments (Cash) [1]	11,069
Individuals (spreading of 600 tons bait at $7.39 per ton)	4,434
Total expenditures from all sources	99,028

[1] Based on Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(7*)*.
[2] 5-year useful life assumed.
[3] Based on data in Annual Report, Texas State Leader of Grasshopper Control *(53*)*.

1940

The fall survey provided proof of the conclusions of all field workers that the control program in 1940 would be insignificant in comparison with programs for 1937, 1938, and 1939. Contrasted with the fall of 1938 when the number of egg beds was not determined but was known to be many and large, most egg beds were definitely located and marked in the fall survey of 1939. Spain *(72*)* summarized the results of the 1939 fall survey and the portent of control in 1940 as follows:

State	Egg beds				
	Number	Average size	Number of egg pods per	Total area infested	Doubtful area
		Acres	*Sq. Ft.*	*Acres*	*Acres*
Colorado	98	19½	4.5	164,000	137,700
New Mexico	101	2½	5.6	30,000	7,000

All egg beds in New Mexico were in Quay and De Baca Counties, south of the area where most of the control work in 1939 was done. No egg beds were known to exist in Oklahoma or Texas. Whereas the infested area in all States in the spring of 1939 was estimated to be more than 11,000,000 acres, it was determined that the infested area in 1940, including all questionable localities, would not exceed 338,700 acres.

Scouting for egg beds from an autogiro was an innovation of the 1939 egg-bed survey. Seated in the cockpit with the pilot, an observer scanned the rangeland for signs indicating the location of beds. Of this, Scharff *(56*)* said:

> in southeastern Pueblo and southwestern Otero Counties, which are known to be infested with egg beds, we found and surveyed one new egg bed of about 60 acres in area which had been missed in the ground survey. The Pueblo County infestation is in rolling prairie country near the foothills with clean grama grass predominating. From the air, I was able to locate and easily distinguished known egg beds from a distance up to five miles. The main characteristic . . . was the fact that they are a much darker gray color than the surrounding dry grasslands. This gray color is evidently the result of very close grazing by the 'hoppers at the time they deposited their eggs, because several areas, which had been grazed by sheep, were of the same grayish hue. It was my experience that the beds became indistinguishable from the surrounding country as we flew over them but were plainly visible at distances from one to three miles.
>
> In the Otero County infestation the topography was of the same rolling character . . . but here the egg beds are situated in an area where there is much yucca, sagebrush, and plants of a grayish color, as well as abundant grama grass. Although I knew the exact location and extent of several egg beds here, I was unable to distinguish between them and the much more numerous areas in the vicinity that were similar in appearance. On the ground some of these egg beds were discernible for more than one-fourth mile.

An autogiro was used for scouting in New Mexico and Texas also. Ohls said *(6*)*: "The autogiro proved to be of great value in survey work. The areas surveyed consisted of large tracts of rangelands with very few roads. . . . Areas, denuded of grass, where 'hoppers have concentrated on egg beds, may be spotted from the air at distances of one-half mile or more at a height of 1,000 feet."

Colorado

Organization for and the conduct of control in Colorado in 1940 followed the same pattern as for the preceding year but on a scale proportionate to the reduced problem known to exist.

Surveys of representative egg beds in Colorado in the spring of 1940 indicated that the overall area infested by *longipennis* was about the same from north to south as it had been in 1939, but that from east to west it was only about 65 percent as wide. Although the infested area was very large, the actual acreage infested with economic populations totaled only about 200,000 acres in 12 different locations. Rodent and bird activity on the more heavily populated egg beds, since the time of the fall survey, had reduced the number of eggs by an average of 35 percent. The desert horned lark was the most important predator observed. After nymphs began to appear, hatching of eggs was delayed and prolonged by unfavorable weather. Delayed and irregular egg hatching increased the duration and extent of control operations. Scharff *(57*)* said: "Throughout much of the infested area, the hatch was delayed as much as 2 weeks as a result of unfavorable weather conditions. Early nymphal mortalilty . . . in some areas resulted in complete control of the infestations. During what should have been the peak of the hatch, where normally populations of 2,000 to 5,000 nymphs per square yard would have been expected, populations at any one time did not exceed 100 per square yard in most cases."

According to records for the 1940 grasshopper survey *(83*)* the general area of infestation in the spring of 1940 agreed almost exactly with the area marked in the fall of 1939 during adult flights. Although additional egg beds were located at hatching time, only two were found that extended beyond the marked areas. Areas shown as questionable territory in the fall survey did not produce infestations.

Speaking of control operations in 1940, Mickle *(42*)* said: "The entire *longipennis* area was baited regardless of ownership. Permission to bait was obtained in each area. Bureau-owned spreader units and Bureau-paid men spread the bait with the cooperation and help of local people. . . . Crews started baiting in the morning as soon as activity among the grasshoppers began and continued generally until ground temperature approached 100°. Ordinarily that was between 6:00 a.m. and 2 p.m. During the peak of control operations 38 mechanical spreaders were in use. About 98 percent of all bait used was distributed by means of mechanical spreaders."

Satisfactory results were obtained with a mixture of 1 part bran and 6 parts sawdust at the first of the season. As the season advanced, and remaining small bands of grasshoppers congregated in green grass along creek bottoms, it was necessary to increase the proportion of bran. In one troublesome case where the small infestation near Wild Horse, Cheyenne County, was the last one remaining in the State, control was not obtained until a pure bran bait was resorted to *(42*)*.

Following is an estimate of expenditures for the control program in Colorado in 1940:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1]	
Materials (cost and freight):	
Bran, 69 tons at $22.67 per ton	1,564
Sawdust, 275 tons at $6.44 per ton	1,771
Sodium arsenite, 3,440 gal. at $0.2909 per gal.	1,001
Supervision (salaries, travel, expense)	4,600
Foremen, truck drivers, laborers (wages)	4,892
Purchased trucks, depreciation [2]	5,000
Purchased bait spreaders, depreciation [2]	500
Operation and maintenance of purchased trucks	1,141
Total	20,469
Other:	
Soil Conservation Service [1] [3]	350
Total expenditures by Federal Government	20,819
State Government: [3]	
Extension Service (salaries and expense, exclusive of county agents)	1,000
Total expenditures from all sources	21,819

[1] Based on data in the Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(82*)*.
[2] 5-year useful life assumed.
[3] Based on Annual Report of State Supervisor of Grasshopper Control, Bureau of Entomology and Plant Quarantine *(42*)*.

New Mexico

Control plans and operations in New Mexico in 1940 were keyed to the reduced problem known to exist. The spring survey corroborated the conclusion reached the preceding fall that economic infestations were confined to only 3 limited areas in 2 counties. About 25,000 acres were infested in De Baca County and, to the north about 50 miles, there was an additional infested area of about 5,000 acres in Quay County *(55*)*.

Hatching began in De Baca County April 11, fully 2 weeks earlier than in recent years, and some eggs were still hatching May 6. Had hatching not been delayed, the brief period of control, as compared with former years, would have been still shorter. Spreader units were operated in formations of three or more because experience from previous years had proven that plan to be the most efficient in range-control work.

"In the *longipennis* area only one mixing station was set up. This was at Tucumcari and provided bait for the infested area in both De Baca and Quay Counties. All costs for mixing and labor for unloading cars at mixing stations were paid by the WPA."—*(21*)*. The proportions of bran and sawdust used were 1 part to 6 parts by volume.

Baiting was conducted with 4 units, from April 22 to May 10, when 3 units were transferred to accelerate control underway in Quay County. The remaining unit was used to scout for and bait any small bands left. At the peak of control, 15 units were operated in Quay County. Baiting began to taper off May 17 and

by May 28 only three units were operating in the State. These were used to bait numerous small bands of grasshoppers ranging from one-half acre to several acres in size with populations of from 10 to 200 per square yard. Baiting ceased entirely June 25 *(55*)*.

The State leader, at the close of the control program, said *(21*)*:

> It is our opinion, based upon a three-year campaign in New Mexico, that meetings held previous to the campaign for the purpose of organizing the area and dividing the responsibilities are more valuable than any other type of meeting that can be held. The 1940 grasshopper control campaign may be considered to be a . . . success . . . in the area which was infested with range hoppers, where 100 percent kill was reported. The success was due to the value of preceding campaigns in materially reducing infested areas, and to the well-organized program that was launched immediately upon the emergence of the hoppers. . . . The results secured during the past three-year period have proved conclusively the value of Bureau-paid-labor control on rangelands.

The last bait in the 1933–40 outbreak was spread June 8, 1940, in Colorado and June 25, 1940, in New Mexico. The distinction of wiping out the last bands of *longipennis* in the 1933–40 outbreak belongs to John M. Landrum and James W. Resley in New Mexico, and Gordon T. Mickle in Colorado, under whose supervision the control work was conducted. "Finis" was written then on control operations that had continued for 4 successive years.

Following is an estimate of expenditures for the control program in New Mexico in 1940:

	Dollars
Federal Government:	
Bureau of Entomology and Plant Quarantine: [1]	
Materials (cost and freight):	
Bran, 55 tons at $22.27 per ton	1,225
Sawdust, 256 tons at $6.44 per ton	1,649
Sodium arsenite, 2,815 gal. at $0.2909 per gal.	819
Supervision (salaries, travel, expense)	4,600
Purchased trucks, depreciation [2]	1,500
Operation and maintenance of purchased trucks	4,000
Foremen, truck drivers, and laborers (wages)	3,871
Total	17,664
Other: [3]	
Soil Conservation Service	228
Civilian Conservation Service	1,113
Works Progress Administration	1,280
Total	2,621
Total expenditures by Federal Government	20,285
State Government: [3]	
Extension Service (salaries and expense exclusive of county agents)	1,000
Total expenditures from all sources	21,285

[1] Based on data in the Annual Grasshopper Control Report, Bureau of Entomology and Plant Quarantine *(82*)*.

[2] 5-year useful life assumed.

[3] Based on data in Annual Report, New Mexico State Leader of Grasshopper Control *(21*)*.

SUMMARY OF CONTROL ACCOMPLISHMENTS AND EXPENDITURES, 1937 TO 1940

No other insect-control undertaking in the West had equalled—in magnitude, scope, and degree of cooperation—that directed against the High Plains grasshopper during the period 1937-40.

Table 19 brings together from the foregoing section on control the expenditures made in each affected State during 1937-40. Included in the tabulation are all control expenditures that were recorded, those that could be calculated from known facts, and those that could be estimated. Conservative estimates are given for many of the contributions.

The value of many contributions could not be included in the tabulation because it was impossible to calculate or estimate them. Among such contributions are: Much of the assistance volunteered by ranchers, agencies, and townspeople; and the cost of repair or replacement of farmers' and ranchers' trucks and automobiles used to haul bait materials and to pull spreaders over roadless, rough terrain.

TABLE 19.—*Number of acres baited and estimated expenditures for controlling the High Plains grasshopper, 1937-40, inclusive*

State and year	Acreage [1]	Estimated expenditures					
		Federal		State	Counties	Individuals	Total
		BE&PQ	Other				
	Acres	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Colorado:							
1937	1,134,800	58,033	73,737	162,182	10,000	41,931	345,883
1938	2,423,664	144,613	141,783	5,118	85,591	131,420	508,525
1939	2,913,018	270,737	61,269	5,000	20,115	35,169	392,290
1940	69,400	20,469	350	1,000	0	0	21,819
Total	6,540,882	493,852	277,139	173,300	115,706	208,520	1,268,517

Kansas:							
1939	16,185	3,155	0	50	474	0	3,679
New Mexico:							
1937	339,000	9,780	4,240	13,128	813	5,026	32,977
1938	1,627,887	77,660	49,000	96,000	10,496	119,995	353,151
1939	1,072,561	116,127	54,737	85,900	0	35,932	292,696
1940	27,000	17,664	2,621	1,000	0	0	21,285
Total	3,066,448	221,231	110,598	196,028	11,309	160,953	700,119
Oklahoma:							
1938	11,000	917	0	250	0	825	1,992
1939	70,425	18,088	1,253	6,000	4,368	2,919	32,628
Total	81,425	19,005	1,253	6,250	4,368	3,744	34,620
Texas:							
1938	687,000	54,080	0	1,000	19,837	44,655	119,572
1939	235,373	67,015	5,253	11,257	11,069	4,434	99,028
Total	922,373	121,095	5,253	12,257	30,906	49,089	218,600
Grand Total	10,627,313	858,338	394,243	387,885	162,763	422,306	2,225,535

[1] Data taken from annual reports of grasshopper control, Bureau of Entomology and Plant Quarantine (*5**, *7**, *47**, *82**).

BIBLIOGRAPHY

Publications

(1) ALBERTSON, F. W., and WEAVER, J. E.
1942. HISTORY OF THE NATIVE VEGETATION OF WESTERN KANSAS DURING 7 YEARS OF CONTINUOUS DROUGHT. Ecol. Monog. 12: [23]–51, illus.

(2) _____ and WEAVER, J. E.
1944. EFFECTS OF DROUGHT, DUST, AND INTENSITY OF GRAZING ON COVER AND YIELD OF SHORT-GRASS PASTURES. Ecol. Monog. 14: [1]–29, illus.

(3) _____ and WEAVER, J. E.
1946. REDUCTION OF UNGRAZED MIXED PRAIRIE TO SHORT GRASS AS A RESULT OF DROUGHT AND DUST. Ecol. Monog. 16: [449]–463, illus.

(4) ALEXANDER, GORDON.
1941. KEYS FOR THE IDENTIFICATION OF COLORADO ORTHOPTERA. Colo. Univ., Studies, Ser. D, 1: 129–164.

(5) AUGHEY, SAMUEL.
1878. NOTES ON THE NATURE OF THE FOOD OF THE BIRDS OF NEBRASKA. U. S. Ent. Comm., Ann. Rpt. Relating to the Rocky Mountain Locust ... (1877) 1: [13]–[62]. (The pages cited are in the appendix.)

(6) BEAL, F. E. L.
1909. THE RELATIONS BETWEEN BIRDS AND INSECTS. U. S. Dept. Agr. Yearbook 1908: 343–350.

(7) BEAMER, RAYMOND [H.]
1917. GRASSHOPPERS OF KANSAS. PART II. THE OEDIPODINAE OF KANSAS. *In* Studies in Kansas Insects. Kans. Univ. Bul., Biol. Ser., 18: 51–126, illus.

(8) BLATCHLEY, W. S.
1920. ORTHOPTERA OF NORTHEASTERN AMERICA. 784 pp., illus. Indianapolis.

(9) BRUNER, LAWRENCE.
1876. NEW SPECIES OF NEBRASKA ACRIDIDAE. Canad. Ent. 8: 123.

(10) _____
1877. LIST OF ACRIDIDAE FOUND IN NEBRASKA. Canad. Ent. 9: 144–145.

(11) _____
1883. NOTES ON OTHER LOCUSTS [THAN THE ROCKY MOUNTAIN LOCUST], AND ON THE WESTERN CRICKET. U. S. Ent. Comm., Rpt. Relating to the Rocky Mountain Locust ... 3: 53–61. (Article contains list of "North American Acrididae North of Mexico.")

(12) _____
1885. FIRST CONTRIBUTION TO A KNOWLEDGE OF THE ORTHOPTERA OF KANSAS. Washburn Col. [Topeka, Kans.] Bul. 1: 125–139.

(13) _____
1891. DESTRUCTIVE LOCUSTS OF NORTH AMERICA, TOGETHER WITH NOTES ON THE OCCURRENCES IN 1891. U. S. Dept. Agr. Div. Ent., Insect Life 4: 18–24. (Also, Canad. Ent. 23: 189–196. 1891, and Ontario Ent. Soc. Ann. Rpt. (1891) 22: 46–50. 1892.)

(14) _____
1892. REPORT ON DESTRUCTIVE LOCUSTS [DURING THE SEASON 1891]. *In* U. S. Dept. Agr. Div. Ent. Bul. 27, pp. 9–33.

(15) _____
1893. A LIST OF NEBRASKA ORTHOPTERA. Nebr. Acad. Sci. Pubs. 3, pp. [19]–33.

(16) _____
1893. THE LONG-WINGED LOCUST OF THE PLAINS (DISSOSTEIRA LONGIPENNIS THOMAS). *In* The More Destructive Locusts of America North of Mexico. U. S. Dept. Agr. Div. Ent. Bul. 28, pp. 36–39, illus. (See *20*.)

(17) _____
1893. REPORT UPON INSECT INJURIES IN NEBRASKA DURING THE SUMMER OF 1892. *In* U. S. Dept. Agr. Div. Ent. Bul. 30, pp. 34–41.

(18) _____
1894. ORTHOPTERA. *In* Report of the Entomologist. Nebr. State Bd. Agr. Ann. Rpt. 1893: 303–317, illus.

(19) _____
1897. GRASSHOPPER REPORT FOR 1895 [AND] GRASSHOPPER REPORT FOR 1896. *In* U. S. Dept. Agr. Div. Ent. Bul. (n. s.) 7, pp. 31–35, 36–39.

(20) _____
1897. THE LONG-WINGED LOCUST OF THE PLAINS (DISSOSTEIRA LONGIPENNIS THOMAS). *In* The Grasshoppers That Occur in Nebraska. Nebr. State Bd. Agr. Ann. Rpt. 1896: 124–127, illus. *(See 16.)*

(21) _____
1899. A PRELIMINARY REPORT ON INSECT ENEMIES OF CLOVER AND ALFALFA. Nebr. State Bd. Agr. Ann. Rpt. 1898: 239–285, illus.

(22) _____
1901. LOCUSTS OR GRASSHOPPERS. Nebr. Agr. Expt. Sta. Bul. 70, pp. 43–54, illus.

(23) _____
1902. GRASSHOPPER NOTES FOR 1901. *In* U. S. Dept. Agr. Div. Ent. Bul. (n. s.) 38, pp. 39–49. (Also *in* Nebr. State Bd. Agr. Ann. Rpt. 1902: 259–294, illus. 1903.)

(24) _____
[1900–1909.] THE ACRIDIIDAE. *In* Biologia Centrali-Americana; Insecta. Orthoptera. Vol. 2, pp. 1–342, illus. (Indexed.) [London.]

(25) CAUDELL, A. N.
1902. NOTES ON ORTHOPTERA FROM OKLAHOMA AND INDIAN TERRITORY, WITH DESCRIPTIONS OF THREE NEW SPECIES. Amer. Ent. Soc. Trans. 28: 83–91.

(26) _____
1903. NOTES ON ORTHOPTERA FROM COLORADO, NEW MEXICO, ARIZONA, AND TEXAS, WITH DESCRIPTIONS OF NEW SPECIES. U. S. Natl. Mus. Proc. 26 (1333): 775–809, illus.

(27) COOK, WILLIAM C.
1925. THE DISTRIBUTION OF THE ALFALFA WEEVIL (PHYTONOMUS POSTICUS GYLL.). A STUDY IN PHYSICAL ECOLOGY. Jour. Agr. Res. 30: 479–491, illus.

(28) CORKINS, C. L.
1922. LONG-WINGED LOCUST OF THE PLAINS. Colo. State Ent. (Ann. Rpt. (1921) 13) Cir. 36, pp. 35-39, illus.

(29) _____
1923. GRASSHOPPER CONTROL IN COLORADO. Colo. [Agr.] Expt. Sta. Bul. 287, 19 pp., illus.

(30) _____
1924. GRASSHOPPERS. *In* Colo. State Ent. (Ann. Rpt. (1923) 15) Cir. 43, pp. 44–48.

(31) COWAN, FRANK T.
1934. HOW TO CONTROL GRASSHOPPERS. Colo. State Ent. Cir. 59, 16 pp., illus.

(32) CRIDDLE, NORMAN.
[1935.] STUDIES IN THE BIOLOGY OF NORTH AMERICAN ACRIDIDAE. DEVELOPMENT AND HABITS. Proc. World's Grain Exhib. and Conf., July 24–Aug. 5, 1933, Regina, Canada. Vol. 2, pp. 474–494. Ottawa.

(33) DAVIS, WATSON.
1937. GRASSHOPPERS IN COLORADO AND KANSAS. Science 86 (2219, Sup.): 9–10.

(34) ESSIG, E. O.
1926. INSECTS OF WESTERN NORTH AMERICA. 1035 pp., illus. New York. (Various reprints.)

(35) FENTON, F. A.
1937. HOW TO CONTROL GRASSHOPPERS IN OKLAHOMA. Okla. Agr. Expt. Sta., Expt. Sta. Bul. 233, 12 pp., illus.

(36) FISHER, A. K.
1893. THE HAWKS AND OWLS OF THE UNITED STATES IN THEIR RELATION TO AGRICULTURE. U. S. Dept. Agr. Div. Ornith. and Mammal., Bul. 3, 210 pp., illus.

(37) [FORBES, S. A.]
1905. DISSOSTEIRA LONGIPENNIS THOMAS. Ill. State Ent. Rpt. 23: 213.

(38) GILLETTE, CLARENCE P.
1904. AN ANNOTATED LIST OF COLORADO ORTHOPTERA. *In* Colo. Agr. Expt. Sta. Bul. 94, pp. 17–56.

(39) HEBARD, MORGAN.
1926. THE ORTHOPTERA OF SOUTH DAKOTA. Acad. Nat. Sci. Phila. Proc. (1925) 77: 33–155, illus.

(40) _____
1930. THE ORTHOPTERA OF COLORADO. Acad. Nat. Sci. Phila. Proc. (1929) 81: 303–425, illus.

(41) _____
1932. THE ORTHOPTERA OF KANSAS. Acad. Nat. Sci. Phila. Proc. (1931) 83: 119–227, illus.

(42) _____
1938. AN ECOLOGICAL SURVEY OF THE ORTHOPTERA OF OKLAHOMA. Okla. Agr. Expt. Sta. Tech. Bul. 5, 31 pp., illus.

(43) HUBBELL, T. H., and ORTENBURGER, A. I.
1927. NOTES ON OKLAHOMA ORTHOPTERA WITH A LIST OF SPECIES FROM THE STATE. Okla. Acad. Sci. Proc. (1926) 6: [149]–183, illus.

(44) HUNTER, S. J.
1898. ON THE OCCURRENCE OF DISSOSTEIRA LONGIPENNIS THOMAS. Psyche 8: [291]–292.

(45) _____
1898. DISSOSTEIRA IN COLORADO. Psyche 8: 299.

(46) _____
1899. ALFALFA AND GRASSHOPPERS. *In* Alfalfa, Grasshoppers, Bees; Their Relationship. Kans. Univ. Dept. Ent. Bul. [6], pp. 3–64, illus.

(47) _____
1902. ELEMENTARY STUDIES IN INSECT LIFE. 344 pp., illus. Topeka, Kansas.

(48) HUNTER, W. D.
1898. DESTRUCTIVE LOCUSTS IN 1897. *In* U. S. Dept. Agr. Div. Ent. Bul. (n. s.) 10, pp. 40–53.

(49) ISELY, F. B.
1944. CORRELATION BETWEEN MANDIBULAR MORPHOLOGY AND FOOD SPECIFICITY IN GRASSHOPPERS. Ent. Soc. Amer. Ann. 37: 47–67, illus.

(50) JOHNSON, WILLARD D.
1901. THE HIGH PLAINS AND THEIR UTILIZATION. U. S. Geol. Survey Ann. Rpt. (1899–1900) 21 (4): 601–741, illus.

(51) KALMBACH, E. R.
1952. BIRDS, BEASTS, AND BUGS. *In* Insects. U. S. Dept. Agr. Yearbook 1952: 724–731.

(52) KELLOGG, VERNON L.
1892. COMMON INJURIOUS INSECTS OF KANSAS. Kans. Univ. Dept. Ent. [Bul. 2], 126 pp., illus.

(53) ———
1892. KANSAS NOTES. U. S. Dept. Agr. Div. Ent., Insect Life 5: 114–116.

(54) KELLY, E. O. G.
1914. A NEW SARCOPHAGID PARASITE OF GRASSHOPPERS. Jour. Agr. Res. 2: 435–446, illus.

(55) KINCER, JOSEPH B.
1923. THE CLIMATE OF THE GREAT PLAINS AS A FACTOR IN THEIR UTILIZATION. Assoc. Amer. Geog. Ann. 13: 67–80, illus.

(56) KIRBY, W. F.
1910. LOCUSTIDAE VEL ACRIDIDAE. *His* A Synonymic Catalogue of Orthoptera v. 3. 674 pp. London (Pub. by British Mus. Nat. Hist.)

(57) KNUTSON, HERBERT.
1937. NOTES ON THE ACRIDIDAE (ORTHOPTERA) OF IOWA. Field and Lab. 5: 37–47, illus.

(58) MCATEE, W. L.
1922. LOCAL SUPPRESSION OF AGRICULTURAL PESTS BY BIRDS. Smithsn. Inst. Ann. Rpt. 1919–20 (Pub. 2622): 411–438, illus.

(59) ———
1926. THE ROLE OF VERTEBRATES IN THE CONTROL OF INSECT PESTS. Smithsn. Inst. Ann. Rpt. 1924–25 (Pub 2836): 415–437, illus.

(60) MARBUT, C. F.
1923. SOILS OF THE GREAT PLAINS. Assoc. Amer. Geog. Ann. 13: 41–66, illus.

(61) MAY, JOHN BICHARD.
1935. THE HAWKS OF NORTH AMERICA. 140 pp., illus. New York (Pub. by Nat'l. Assoc. Audubon Socs.)

(62) MERRILL, D. E.
1916. GRASSHOPPER CONTROL. N. Mex. Agr. Expt. Sta. Bul. 102, 32 pp., illus.

(63) MILLIKEN, ROBERT.
1893. REPORT ON OUTBREAKS OF THE WESTERN CRICKET AND OF CERTAIN LOCUSTS IN IDAHO. U. S. Dept. Agr. Div. Ent., Insect Life 6: 17–24.

(64) MORSE, ALBERT PITTS.
1907. FURTHER RESEARCHES ON NORTH AMERICAN ACRIDIIDAE. Carnegie Inst. Wash. Pub. 68, 54 pp., illus.

(65) MUESEBECK, C. F. W.
1950. COMMON NAMES OF INSECTS APPROVED BY THE AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS. Jour. Econ. Ent. 43: 117–138.

(66) OSBORN, HERBERT.
1891. REPORT OF A TRIP TO KANSAS TO INVESTIGATE REPORTED DAMAGES FROM GRASSHOPPERS. U. S. Dept. Agr. Div. Ent., Insect Life 4: 49–56. (Also, Ontario Ent. Soc. Ann. Rpt. (1891) 22: 69–74. 1892, and U. S. Dept. Agr. Div. Ent., Bul. 27, pp. 58–64. 1892.)

(67) PATCH, EDITH M.
1913. LIST OF INSECTS RECORDED ON POTATO. *In* Johansen, A. C., Potato Flea Beetle. Maine Agr. Expt. Sta. Bul. 211, pp. 51–56.

(68) POPENOE, E. A.
1891. NOTES ON THE RECENT OUTBREAK OF DISSOSTEIRA LONGIPENNIS. (Abstract) U. S. Dept. Agr. Div. Ent., Insect Life 4: 41. (Information supplied by Bruner, Popenoe, and Osborn follows abstract, pp. 41–42.) (Also, Ontario Ent. Soc. Ann. Rpt. (1891) 22: 63. 1892.)

(69) REHN, JAMES A. G., and HEBARD, MORGAN.
1906. A CONTRIBUTION TO THE KNOWLEDGE OF THE ORTHOPTERA OF MONTANA, YELLOWSTONE PARK, UTAH AND COLORADO. Acad. Nat. Sci. Phila. Proc. 58: 358–418, illus.

(70) RILEY, C. V.
1884. ORTHOPTERA. *In* Kingsley, J. S., *ed.*, Crustacea and Insects—Kingsley's The Standard Natural History v. 2, pp. 167–203, illus. Boston.

(71) [_____]
1891. LOCUST RAVAGES OF THE PRESENT YEAR. U. S. Dept. Agr. Div. Ent., Insect Life 3: 438.

(72) _____
1892. THE LOCUST OR GRASSHOPPER OUTLOOK. (Abstract) Amer. Assoc. Adv. Sci. Proc. (1891) 40: 423–425. (Abstract also *in* U. S. Dept. Agr. Div. Ent., Insect Life 4: 321–323. 1892.—(a printing prior to that in the Proceedings.)

(73) ROCKWOOD, L. P.
1925. ON NIGHT FLYING AND ATTRACTION TO LIGHT IN ACRIDIIDAE AND THE RELATION OF METEOROLOGICAL CONDITIONS THERETO. Pan-Pacific. Ent. 2: 36–38.

(73a) SAILER, REEVES I.
1955. COMMON NAMES OF INSECTS APPROVED BY THE ENTOMOLOGICAL SOCIETY OF AMERICA. Bul. Ent. Soc. Amer. v. 1, No. 4, 36 pp.

(74) SAUSSURE, H. DE.
1884. PRODROMUS OEDIPODIORUM. INSECTORUM EX ORDINE ORTHOPTERORUM. Soc. de Phys. et Hist. Nat., Genèva, Mém. v. 28, No. 9, 254 pp., illus. (Also, his Additamenta . . . *Ibid.* v. 30, No. 1, 180 pp., illus. 1888.)

(75) SCUDDER, SAMUEL H.
1876. REPORT ON THE ORTHOPTERA COLLECTED BY THE UNITED STATES GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN, UNDER THE DIRECTION OF LIEUTENANT GEORGE M. WHEELER, DURING THE SEASON OF 1875. U. S. Chief of Engineers, Ann. Rpt. 1875–76 (App. JJ): 278–295. (The Orthoptera report itself is designated Appendix H9; reprinted (1876) as extract from Appendix JJ.)

(76) _____
1901. CATALOGUE OF THE DESCRIBED ORTHOPTERA OF THE UNITED STATES AND CANADA. Davenport [Iowa] Acad. Nat. Sci. Proc. (1899–1900) 8: 1–101, illus.

(77) _____ and COCKERELL, THEODORE D. A.
1904. A FIRST LIST OF THE ORTHOPTERA OF NEW MEXICO. Davenport [Iowa] Acad. Sci. Proc. (1901–3) 9: 1–60, illus.

(78) SHANTZ, H. L.
1923. THE NATURAL VEGETATION OF THE GREAT PLAINS REGION. Assoc. Amer. Geog. Ann. 13: 81–107, illus.

(79) _____ and ZON, RAPHAEL.
1936. THE NATURAL VEGETATION OF THE UNITED STATES. *In* U. S. Dept. Agr., Atlas of American Agriculture, Physical Basis . . ., 29 pp., illus. (Originally published 1924 as Advance Sheet 6 (sec. E of pt. 1, The Physical Basis of Agriculture)—contribution of U. S. Bur. Agr. Econ.)

(80) SHOTWELL, ROBERT L.
1936. THE SPECIES AND DISTRIBUTION OF GRASSHOPPERS IN THE 1935 OUTBREAK. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 16 (5, Sup.): 213–259. [Processed.]

(81) _____
1937. THE SPECIES AND DISTRIBUTION OF GRASSHOPPERS IN THE 1936 OUTBREAK. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 17 (3, Sup.): 117–150. [Processed.]

(82) _____
1938. THE SPECIES AND DISTRIBUTION OF GRASSHOPPERS IN THE 1937 OUTBREAK. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 18 (6, Sup.): 385–443. [Processed.]

(83) _____
1938. SPECIES AND DISTRIBUTION OF GRASSHOPPERS RESPONSIBLE FOR RECENT OUTBREAKS. Jour. Econ. Ent. 31: 602–610.

(84) _____
1939. THE SPECIES AND DISTRIBUTION OF GRASSHOPPERS IN THE 1938 OUTBREAK. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 19 (4, Sup.): 179–270, illus. [Processed.]

(85) _____
1941. THE SPECIES AND DISTRIBUTION OF GRASSHOPPERS IN THE 1939 OUTBREAK. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 21 (5, Sup.): [295]–395. [Processed.]

(86) _____ and SKOOG, F. E.
1942. TRENDS OF GRASSHOPPER POPULATIONS IN THE AREAS OF MAJOR OUTBREAKS. 1940 AND 1941. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 22 (3, Sup.): 75–90. [Processed.]

(87) SMITH, HARRISON E.
1915. THE GRASSHOPPER OUTBREAK IN NEW MEXICO DURING THE SUMMER OF 1913. U. S. Dept. Agr. Bul. 293, 12 pp., illus.

(88) SMITH, ROGER C., KELLY, E. G., DEAN, GEO. A., and others.
1943. DESCRIPTION OF KANSAS INSECTS. Kans. State Bd. Agr. Rpt. v. 62, No. 255, 440 pp., illus.

(89) SNOW, F. H.
1891. THE CHINCH BUG DISEASE AND OTHER NOTES. U. S. Dept. Agr. Div. Ent., Insect Life 4: 69–72.

(90) _____ and HUNTER, S. J.
1897. THE MORE DESTRUCTIVE GRASSHOPPERS OF KANSAS. Kans. Univ. Dept. Ent. Bul. [4], 11 pp., illus.

(91) SORAUER, PAUL.
1925. DISSOSTEIRA SCUDD. *In his* Handbuch der Pflanzenkrankheiten, aufl. 4, bd. 4, teil 1, p. 209. Berlin.

(92) STILES, C. F., SCHOLL, F. E., and FENTON, F. A.
1937. THE 1936 GRASSHOPPER OUTBREAK IN OKLAHOMA. Jour. Econ. Ent. 30: 768–771.

(93) THOMAS, CYRUS.
1872. NOTES ON THE SALTATORIAL ORTHOPTERA OF THE ROCKY MOUNTAIN REGIONS. U. S. Geol. [Survey of the Territories], Survey of Montana and Portions of Adjacent Territory, by F. V. Hayden, U. S. Geologist, Ann. Rpt. Prog. 5: 423–466, illus.

(94) _____
1873. SYNOPSIS OF THE ACRIDIDAE OF NORTH AMERICA. U. S. Geol. Survey of the Territories, by F. V. Hayden, U. S. Geologist-in-Charge, Rpt. 5 (1): [1]–190, illus.

(95) TINKHAM, E. R.
1938. WESTERN ORTHOPTERA ATTRACTED TO LIGHTS. N. Y. Ent. Soc. Jour. 46: 339–353.

(96) _____
1948. FAUNISTIC AND ECOLOGICAL STUDIES ON THE ORTHOPTERA OF THE BIG BEND REGION OF TRANS-PECOS TEXAS, WITH ESPECIAL REFERENCE TO THE ORTHOPTERAN ZONES AND FAUNAE OF MIDWESTERN NORTH AMERICA. Amer. Midland Nat. 40: 521–663, illus.

(97) TUCKER, ELBERT S.
1906. COLLECTING INSECTS AT NIGHT. Kans. Acad Sci. Trans. (1905) 20: 108–120.

(98) _____
1907. SOME RESULTS OF DESULTORY COLLECTING OF INSECTS IN KANSAS AND COLORADO. Kans. Univ. Sci. Bul. 4: 51–112.

(99) UHLER, P. R.
1877. REPORT UPON THE INSECTS COLLECTED BY P. R. UHLER DURING THE EXPLORATIONS OF 1875 ... U. S. Geol. and Geog. Survey of the Territories, by F. V. Hayden, U. S. Geologist-in-Charge, Bul. 3 (4): 765–796. (Appendix to article, by A. R. Grote, pp. [797]–801.)

(100) UNITED STATES GEOLOGICAL SURVEY.
1934. UNITED STATES RELIEF MAP. Washington, D. C. (Originally issued 1916.)

(101) [UNITED STATES] GREAT PLAINS COMMITTEE.
1936. THE FUTURE OF THE GREAT PLAINS. 194 pp., illus. Washington, D. C.

(102) UNITED STATES WEATHER BUREAU.
1892–1957. CLIMATOLOGICAL DATA [–FOR COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, AND TEXAS]. (Monthly and annual reports by States and sections. After June 1909 the series now known as Climatological Data was published under this title; the Climatological Data, so designated, were published in U. S. Weather Bur. Monthly Weather Rev. until 1914. Oklahoma data were first issued Aug. 1892; for the other States here mentioned data first issued 1896-98; earlier, the weather reports in organized form for these areas were issued by the State (or Territory), as early as 1879 and 1887 (Nebraska and Kansas).)

(103) UVAROV, B. P.
1928. LOCUSTS AND GRASSHOPPERS. A HANDBOOK FOR THEIR STUDY AND CONTROL. 352 pp., illus. London. (Pub. by Imp. Bur. Ent.)

(104) VISHER, STEPHEN SARGENT.
1923. LAWS OF TEMPERATURE. Assoc. Amer. Geog. Ann. 13: 15–40.

(105) WALTON, W. R.
1916. GRASSHOPPER CONTROL IN RELATION TO CEREAL AND FORAGE CROPS. U. S. Dept. Agr. Farmers' Bul. 747, 18 pp., illus. (Rev. 1922.)

(106) WARREN, EDWARD ROYAL.
1942. THE MAMMALS OF COLORADO. THEIR HABITS AND DISTRIBUTION. Ed. 2, 330 pp., illus. Norman, [Okla.]

(107) WEAVER, J. E., and ALBERTSON, F. W.
1940. DETERIORATION OF MIDWESTERN RANGES. Ecology 21: 216–236, illus.

(108) _____ and CLEMENTS, FREDERIC E.
1929. PLANT ECOLOGY. 520 pp., illus. New York.

Mimeographed Reports, Typewritten Reports, Insect Collections, Correspondence, Manuscripts

(1*) ALEXANDER, GORDON.
1951. LETTER TO C. WAKELAND 9/1/51, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE INSECT COLLECTION OF THE UNIVERSITY OF COLORADO.

(2*) BOYKIN, G. L.
1937. GRASSHOPPER CONTROL. N. Mex. Agr. Ext. Serv., State Leader Grasshopper Cont. Ann. Rpt.

(3*) DAVIS, LOUIS G., and MICKLE, GORDON T.
1939. ANNUAL REPORT ON GRASSHOPPER CONTROL. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rept.

(4*) _____
1939. MIGRATORY GRASSHOPPER CONTROL CAMPAIGN, COLORADO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rept.

(5*) DOVE, W. E.
1938. GRASSHOPPER CONTROL CAMPAIGN, 1938. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(6*) _____
1939. RECORDS FOR GRASSHOPPER EGG AND NYMPH SURVEY FOR 1939, ORIGINAL FIELD NOTES. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(7*) _____
1939. WEEKLY, ANNUAL, AND SPECIAL REPORTS ON GRASSHOPPER CONTROL. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(8*) DUTTON, JIM R.
1952. RECORDS FOR GRASSHOPPER SURVEY, 1952. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Grasshopper Cont. Proj.

(8a*) _____
1955. RECORDS FOR GRASSHOPPER SURVEY, 1955. U. S. Dept. Agr., Agr. Res. Serv., Plant Pest Control Branch, Grasshopper Cont. Proj.

(8b*) _____
1956. RECORDS FOR GRASSHOPPER SURVEY, 1956. U. S. Dept. Agr., Agr. Res. Serv., Plant Pest Control Branch, Grasshopper Cont. Proj.

(8c*) _____
1957. PROGRAM ANNUAL REPORT 1956–57. U. S. Dept. Agr., Agr. Res. Serv., Plant Pest Control Div., Western Region, Grasshopper Cont. Proj.

(9*) EYER, J. R., and STEWARD, H. C.
1934. FALL GRASSHOPPER POPULATION AND EGG SURVEY, NEW MEXICO, 1934. N. Mex. Agr. Ext. Serv.

(10*) FENTON, F. A.
1936. GRASSHOPPER CONTROL, 1936. Okla. State Leader of Grasshopper Cont. Ann. Rpt.

(11*) ———
1937. GRASSHOPPER CONTROL, 1937. Okla. State Leader of Grasshopper Cont. Ann. Rept.

(12*) GADDIS, B. M.
1938. REPORT OF ACTIVITIES CONDUCTED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE WITH FUNDS PROVIDED FOR THE CONTROL OF INCIPIENT AND EMERGENCY OUTBREAKS OF INSECT PESTS OR PLANT DISEASES. U. S. Dept. Agr. mimeo.

(13*) GINN, W. M.
1937. GRASSHOPPER SURVEY, NEW MEXICO. N. Mex. Agr. Ext. Serv.

(14*)_____
1937. SUMMARY OF GRASSHOPPER SURVEY, NEW MEXICO. N. Mex. State Col.

(15*) GURNEY, ASHLEY B.
1951. LETTERS TO C. WAKELAND, MAY 4 AND AUGUST 23, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF U. S. NATIONAL MUSEUM.

(16*) _____
1951. LETTER TO C. WAKELAND, JULY 3, 1951, LISTING DISSOSTEIRA LONGIPENNIS SPECIMENS IN THE COLLECTION OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

(17*) _____
1951–55. LETTERS TO C. WAKELAND, AUGUST 23, 1951, AND FEBRUARY 21, 1955, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTIONS OF MICHIGAN STATE COLLEGE AND IN THE MUSEUM OF ZOOLOGY, UNIVERSITY OF MICHIGAN.

(18*) HAUKE, HAROLD A.
1951. LETTER TO C. WAKELAND, JUNE 1, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF THE UNIVERSITY OF NEBRASKA.

(19*) HILDWEIN, H. L.
1938. GRASSHOPPER CONTROL, 1938. N. Mex. State Leader of Grasshopper Cont. Ann. Rpt.

(20*) _____
1939. GRASSHOPPER CONTROL, 1939. N. Mex. State Leader of Grasshopper Cont. Ann. Rpt.

(21*) _____
1940. GRASSHOPPER CONTROL. N. Mex. Agr. Ext. Serv., State Leader Grasshopper Cont. Ann. Rpt.

(22*) HINKLE, GALEN A.
1938. THE RELATION OF GRASSHOPPERS (WITH SPECIAL EMPHASIS ON DISSOSTEIRA LONGIPENNIS) TO THE NATIVE RANGES OF COLORADO. Unpublished thesis for M. S. degree, Colo. A. & M. Col., 186 pp., illus.

(23*) HOIDALE, P. A.
1951. RECORDS FOR GRASSHOPPER SURVEY FOR 1951. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Grasshopper Cont.

(24*) HOLLINGER, E. C.
1936. LETTER TO V. L. WILDERMUTH, SEPTEMBER 16, 1936.

(25*) HOYT, AVERY S.
1938. OUTLINE OF PLAN OF OPERATIONS FOR COOPERATIVE PROTECTION OF CROPS AGAINST GRASSHOPPERS DURING 1939. U. S. Dept. Agr. mimeo., Dec. 15.

(26*) HUNGERFORD, H. B.
1951. LETTER TO C. WAKELAND, MAY 31, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN COLLECTION OF UNIVERSITY OF KANSAS.

(27*) KELLY, E. O. G.
1938. GRASSHOPPER CONTROL. Kans. State Leader of Grasshopper Cont. Ann. Rpt.

(28*) _____
1939. GRASSHOPPER CONTROL, 1939. Kans. State Leader of Grasshopper Cont. Ann. Rpt.

(29*) KROPF, FRED H.
1938–40. ORIGINAL NOTES, UNPUBLISHED. (2 years.)

(30*) LANDRUM, JOHN M.
1937. ANNUAL REPORT OF GRASSHOPPER CAMPAIGN IN NEW MEXICO, OKLAHOMA, AND TEXAS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(31*) _____
1938. ANNUAL REPORT CONTROL PROGRAM, NEW MEXICO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rept.

(32*) _____
1951. LETTER TO C. WAKELAND, OCTOBER 26, 1951.

(33*) MCCAMPBELL, SAM C.
1934. GRASSHOPPER CONTROL, 1934. Colo. Agr. Ext. Serv., Ann. Rpt. Ext. Ent. to Dir. Ext.

(34*) _____
1934. GRASSHOPPER CONTROL, 1934. Colo. Agr. Ext. Serv. Ann. Rpt. Ext. Ent.

(35*) _____
1936. GRASSHOPPER CONTROL, 1936. Colo. Agr. Ext. Serv., Ann. Rpt. Ext. Ent. to Dir. Ext. 1936: 73–74.

(36*) _____
1936. GRASSHOPPER CONTROL, 1936. Colo. State Leader of Grasshopper Cont. Ann. Rpt.

(37*) _____
1937. GRASSHOPPER CONTROL, 1937. Colo. Ext. Serv., Weekly grasshopper campaign Rpts.

(38*) _____
1937. GRASSHOPPER CONTROL, 1937. Colo. State Leader of Grasshopper Cont. Weekly and Ann. Rpts.

(39*) _____
1937. SUMMARY OF FUNDS SPENT IN 1937 GRASSHOPPER CAMPAIGN, AND FUNDS NEEDED FOR 1938 GRASSHOPPER CAMPAIGN. Report attached to letter to F. A. Anderson, Oct. 7, 1937.

(40*) _____
1938. GRASSHOPPER CONTROL, 1938. Colo. State Leader of Grasshopper Cont. Weekly and Ann. Rpts.

(41*) _____
1939. GRASSHOPPER CONTROL, 1939. Colo. State Leader of Grasshopper Cont. Ann. Rpt.

(42*) MICKLE, GORDON T.
1940. GRASSHOPPER CONTROL, COLORADO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rpt.

(43*) _____
1951. LETTER TO C. WAKELAND, AUGUST 20, 1951, CONCERNING THE OCCURRENCE OF DISSOSTEIRA LONGIPENNIS IN COLORADO IN 1948 AND 1949.

(44*) MILLER, ARTHUR A.
1939. GRASSHOPPER CONTROL, OKLAHOMA. U. S. Dept. Agr., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rpt.

(45*) MONTANA STATE COLLEGE.
—— SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE INSECT COLLECTION. Bozeman, Mont.

(46*) PARKER, J. R.
1935. GRASSHOPPER CONTROL CAMPAIGN REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(47*) _____
1937. ANNUAL REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(48*) _____
1937. QUARTERLY REPORT, JULY 1–SEPTEMBER 30. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(49*) _____ and SHOTWELL, ROBERT L.
1936. SUMMARY OF GRASSHOPPER CONDITIONS DURING 1936. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(50*) PFADT, R. E.
1951. LETTER TO C. WAKELAND, JUNE 6, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION, UNIVERSITY OF WYOMING.

(51*) REINHARD, H. J.
1951. LETTERS TO C. WAKELAND, JUNE 8 AND JUNE 19, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF THE TEXAS COLLEGE OF AGRICULTURE AND MECHANICAL ARTS.

(52*) REPPERT, R. R.
1938. GRASSHOPPER REPORT FOR TEXAS. Tex. Agr. Ext. Serv.

(53*) _____
1939. THE TEXAS GRASSHOPPER CAMPAIGN OF 1938 AND PROSPECTS FOR 1939. Tex. Agr. Ext. Serv. mimeo. (Unnumbered.)

(54*) RESLEY, JAMES W.
1939. GRASSHOPPER CONTROL, NEW MEXICO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rept.

(55*) _____
1940. GRASSHOPPER CONTROL, NEW MEXICO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rpt.

(56*) SCHARFF, DONALD K.
1939. WEEKLY, ANNUAL, AND SPECIAL SURVEY REPORTS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(57*) _____
1940. WEEKLY, ANNUAL, AND SPECIAL SURVEY REPORTS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(58*) SEVERIN, H. C.
1951. LETTER TO C. WAKELAND, JUNE 1, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF THE SOUTH DAKOTA STATE COLLEGE.

(59*) SHOTWELL, ROBERT L.
1935. ANNUAL SURVEY REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(60*) _____
1935. GRASSHOPPER COLLECTION RECORDS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(61*) _____
1936. ANNUAL SURVEY REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(62*) _____
1937. ANNUAL SURVEY REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(63*) _____
1937. GRASSHOPPER COLLECTION RECORDS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Cereal and Forage Insect Invest., Lab., Bozeman, Mont.

(64*) _____
1938. ANNUAL SURVEY REPORT. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(65*) _____
1938. GRASSHOPPER COLLECTION RECORDS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(66*) _____
1938. GRASSHOPPER SURVEY, NEW MEXICO. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(67*) _____
1939. GRASSHOPPER COLLECTION RECORDS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(68*) _____
1939. SURVEY OF GRASSHOPPER CONDITIONS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(69*) _____
1940. GRASSHOPPER COLLECTION RECORDS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(70*) SMITH, ROGER C.
1951. LETTER TO C. WAKELAND, MAY 31, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF KANSAS STATE AGRICULTURAL COLLEGE.

(71*) SPAIN, LOUIS A.
1939. REPORT OF NYMPHAL SURVEY. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(72*) _____
1939. REPORT OF THE DISSOSTEIRA LONGIPENNIS AREA. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(73*) SPICER, WILLIAM J.
1939. GRASSHOPPER CONTROL, TEXAS. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj. Supervisor's Ann. Rpt.

(74*) STILES, C. F.
1936. ANNUAL REPORT OF GRASSHOPPER CONTROL. Okla. Agr. Ext. Serv.

(75*) _____
1938. GRASSHOPPER CONTROL. Okla. State Leader of Grasshopper Cont. Ann. Rpt.

(76*) _____
1939. GRASSHOPPER CONTROL. Okla. State Leader of Grasshopper Cont. Ann. Rpt.

(77*) _____
1951. LETTER TO C. WAKELAND, MAY 17, 1951, LISTING SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE COLLECTION OF OKLAHOMA A. AND M. COLLEGE.

(78*) STRONG, LEE A.
1937. INFORMATION ON PROCEDURE AND PLAN OF OPERATION FOR COOPERATIVE CAMPAIGN FOR GRASSHOPPER CONTROL. U. S. Dept. Agr. mimeo.

(79*) _____
1939. STATEMENT TO STATE OFFICIALS AND OTHERS WHO ARE COOPFRATING WITH THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE, U. S. DEPARTMENT OF AGRICULTURE, IN COMBATTING INCIPIENT AND EMERGENCY OUTBREAKS OF PLANT PESTS. U. S. Dept. Agr. mimeo., March 6.

(80*) SWENK, M. H.
1936. REPORT OF THE RESOLUTIONS COMMITTEE OF THE STATE OFFICIALS CONCERNED WITH INSECT CONTROL OPERATIONS. Mimeo., Omaha, Nebr., Dec. 5.

(81*) UNITED STATES DEPARTMENT OF AGRICULTURE.
_____ SPECIMENS OF DISSOSTEIRA LONGIPENNIS IN THE INSECT COLLECTION. U. S. Dept. Agr., Agr. Res. Serv., Ent. Res. Div., Lab., Bozeman, Mont.

(82*) WAKELAND, CLAUDE
1940. ANNUAL REPORT, GRASSHOPPER AND MORMON CRICKET CONTROL. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(83*) _____
1940. RECORDS FOR GRASSHOPPER SURVEY IN 1940, ORIGINAL FIELD NOTES. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(84*) _____
1941. RECORDS FOR GRASSHOPPER SURVEY, 1941. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Dom. Plant Quar., Grasshopper Cont. Proj.

(85*) _____
1948. RECORDS FOR GRASSHOPPER SURVEY IN 1948. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Grasshopper Cont.

(86*) _____
1950. RECORDS OF GRASSHOPPER SURVEY FOR 1950. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Div. Grasshopper Cont.

(87*) WEYL, VAL E.
1951. LETTER TO C. WAKELAND, AUGUST 2, 1951, VERIFYING COLLECTING DISSOSTEIRA LONGIPENNIS IN SOUTH DAKOTA.

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